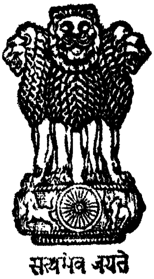

INDIAN AGRICULTURAL
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PROCEEDINGS AND INDEX

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXV JANUARY 1934 No. 1

PROCEEDINGS

Midlands Section

Meeting at the College of Art and Technology, Leicester, on Thursday, 16th November 1933; Mr. T. Morley in the chair.

MODERN METHODS OF UNDERWEAR MANUFACTURE

A lecture on the above-named subject was delivered to members of the Midlands Section of the Institute by Mr. A. Wilfred Swann, of Leicester. The lecturer divided his subject into three parts, dealing first with underwear of the past, next with present-day garments, and finally venturing into discussion of styles and fabrics of the future; parts one and two were adequately illustrated by samples. He pointed out that the older types of garments were nowadays considered heavy and cumbersome but that good quality was usually associated with these goods. Modern underwear might be said to commence with the introduction of Directoire or closed style knickers about 1908 and, up to the war, this trade was practically confined to German firms. The fabrics used were made on Terrot type machines and usually knitted from two threads 40/1's cotton with a loop of condenser cotton at the back laid over every three needles. The fabric was finally brushed on a Gestner-type raising and knapping machine. Elastic was inserted by sewing machines into the top and legs. Shortly after the war a change to even lighter fabrics began and this aspect is still characteristic of underwear. About 1920, continued Mr. Swann, British Celanese Ltd. introduced underwear of Celanese yarn made on a Terrot type machine and these sold well. Interlock-machine-made fabrics came also into prominence and such well-known trade names as "Meridian", "Vedonis", and "Velvetex" were associated with these goods. When some four years ago, the patents on these machines expired, large numbers of them were installed and fabrics made thereon are made up into vests, combinations, men's and boy's shirts and pants. Cotton is used principally but dulled rayon is coming into this use now.

The lecturer also referred to a machine for the automatic insertion of elastic, the use of which every buyer insisted upon, and pointed out that improvements in the machine now enabled the elastic to be replaced easily. Reference was also made to recent developments in the direction of securing a closer fit in underwear and more particularly in knickers. Two examples of these garments were shown.

Dealing with the future and tendencies in manufacture and method, Mr. Swann gave particulars of some of the latest ranges of garments available. He also referred to the introduction of "Lastex" yarn which, inserted in the fabric by means of a new type of knitting machine, makes a clinging type of garment which does not need additional elastic.

Mr. Swann received subsequently the hearty thanks of the meeting for his interesting paper.

On Wednesday, December 13th, a party of members of the Midland Section of the Institute paid a visit of inspection to the Brook Mills of Messrs. G. H.

Heath & Co. Ltd., at Sandbach, Cheshire, the arrangements being carried out by Mr. T. A. Purt, Honorary Secretary of the Section. Silk-throwing was demonstrated, from the imported silk to the finished yarns. Col. G. N. Heath met the visitors and the inspection proceeded in small groups, the various processes being fully explained en route, including yarn clearing devices and the operation of self-lubricating rings. Tea was provided in the works canteen, and on the motion of Mr. J. Chamberlain (Leicester) a hearty vote of thanks was accorded to Col. Heath, who, in acknowledging the vote, said he welcomed the visit because he appreciated the value of interchange of visits between the various sections of the industry.

Scottish Section

MEETING AT EDINBURGH

A meeting of the members of the Scottish Section of the Institute took place at the Edinburgh School of Salesmanship on Thursday, December 21st. An invitation was extended to students of the textile classes conducted at the school and there was a good attendance. Mr. J. P. Beveridge (Dunfermline) occupied the chair and welcomed Mr. W. Wilkinson, O.B.E., F.T.I., who contributed an address on the subject of "Problems in Weaving". Mr. Wilkinson dealt particularly with the weaving of poplins, warp satins, voiles, and crêpes, describing the weaving requirements in closest detail. He also referred to experimental work which he had more recently carried out involving the use of Lastex thread, and exhibited a number of specimens of resultant woven material.

At the conclusion of his address, Mr. Wilkinson, by way of illustration of various aspects of weaving operations, presented a cinema display with explanatory observations.

Mr. Angus Robertson (Dunfermline) moved a vote of thanks to the lecturer and expressed warm appreciation of the very clear and unmistakable manner in which the various operations of weaving had been described. The vote was heartily accorded as was also a similar vote to the principal of the school.

London Section

Meeting at the London Rooms of the Institute, 104/5 Newgate Street, on Monday, 20th November 1933; Mr. John Howard in the Chair.

FABRICS FOR INDUSTRIAL PURPOSES

Mr. R. S. Meredith was the lecturer on this occasion, said the Chairman, and he was sure members would have an interesting evening.

The lecturer, thanking the Chairman for his presence and kind introduction, said he hoped members afterwards would raise as many points for discussion as possible. He first asked for consideration as to the proper functioning of fabrics for industrial purposes. He pointed out that when he first entered the industry he had been astonished at the ignorance of the manufacturer of the ultimate use of the textiles they produced. No direct contact between the manufacturer and the maker-up existed; it was indeed difficult for the manufacturer to ascertain the precise function that any given fabric had to perform. To-day the position was almost completely changed and makers-up could purchase direct from the manufacturer. The road to co-operation was being cleared though obstructions, caused largely by want of confidence, still existed. The lecturer pleaded for more consultation between the two sections of the industry, as each had much to learn from the other. As an illustration of his point that the manufacturer and maker-up ought to know more of each other's share in the industry, Mr. Meredith referred to the growing demand for tents and pointed out that the canvas employed could make or mar a holiday. He said that tent material, whether flax or cotton, should be so constructed that when subject to rope strains it gave its best functioning value. The conditions under which the fabric was used in a correctly-made and correctly-erected tent altered the construction as delivered. He contended that rope-strain put the main pull in the warp direction and transferred much of the warp crimping into the weft; it reduced the number of yarns weft-ways and increased the number warp-ways in any given measurement. Such fabrics made by our grandparents for sails had to be such that the original strength of the canvas weft-way was 50% that of the warp. It was also so constructed as not to tear readily. Mr. Meredith then referred to certain committees appointed to consider fabrics for the manufacture of tents, marquees, hangars, etc. for Government departments. He had served on several of these Committees and he submitted that this meant that, at long last, it was being recognised that to secure the best fabric structure it was necessary to know the purpose for which it was intended. He gave instances of the utilisation of fabrics under conditions to which they should not have been subjected. He urged that the class of raw material, the preparation of the material, the spinning, weaving, finishing, the maker-up, and the user of the finished article should co-operate in the production of fabrics for industrial purposes.

Turning again to tent ducks the lecturer gave particulars of some experiments carried out to show what changes in the construction of a fabric took place when under tension. "Two split lengths of flax tent duck—a Government standard quality—were seamed together with a run and fell seam—the usual seam for tentage—and had tabled sides, to give relatively what is done in making-up tentage. The piece was exposed and stretched for 28 days in the open and showed the following remarkable changes.

(1) Weight decreased from 13·67 to 13·49 oz. per sq. yard.
Warp stretched by 1·16 in. in every foot.
Warp counts, increased from 38 to 42 per inch.
Weft counts, decreased from 28·5 to 24·25 per inch.
Warp crimp of yarns, decreased from 23·7% to 9·7%.
Weft crimp of yarns, increased from 3·5% to 11%.
Warp breaking strength (2 in. strips), increased from 401 to 508 lb.
Weft breaking strength (2 in. strips), decreased from 667 to 560 lb.

Cotton duck was also tested in exactly the same way with the following results—
Weight decreased from 13·46 to 13·2 oz. per square yard.
Warp stretched ·78 in. in every foot.
Warp counts, increased from 45 to 47 per inch.
Weft counts, decreased from 41·5 to 38 per inch.
Warp crimp of yarns, decreased from 22% to 14·5%.
Weft crimp of yarns, increased from 6 % to 11·5%.
Warp breaking strength (2 in. strips), increased from 340 to 391 lb.
Weft breaking strength (2 in. strips), decreased from 321 to 286 lb."

If this duck had been made correctly it would have had a much greater weft strength in the new material, so as to allow for the considerable change in structure and therefore in tensile strengths which take place when it is called upon to function.

The lecturer urged the importance of the tearing test in application to tent ducks and similar fabrics on the grounds that such tests disclose both lack of strength and bad construction. In such fabrics what was wanted was a construction which gave the best results in use—different uses would then give some indication as to requirements in construction. Without all the knowledge required for a complete judgment erroneous conclusions would be reached. Mr. Meredith repeated that he sympathised with the laundry industry when blamed for damaging fabrics in laundering. In his view the cause of much laundry damage was adulteration of fabrics by mixing fibres in yarn or cloth. Fibres react differently under similar conditions and tend to wear each other out. He strongly deprecated proposals to increase weft extensibility which he was sure would increase the difficulties encountered in the making-up and laundry industries.

DISCUSSION

The Chairman drew a distinction between the distribution methods of 40 years ago and those of to-day. He claimed that then "quality" was the selling factor, but that now "design, colour, or fashion" regulated sales. He thought that sail-makers had learnt by years of experience and by always aiming at a better construction for the purpose in view. He gave instances of fabrics in which trade had been lost by adulteration and by reduction in "quality", such as that in corduroy for railway employees, which he regarded as one of the biggest losses sustained by the Lancashire trade. He said that to-day it was nearly impossible to buy a good suit of army overalls.

Mr. L. J. Mills referred to the statement made by the lecturer that rope-pull on a tent fabric when applied in the warp direction transferred much of the warp crimping to the weft. He suggested that this effect was perhaps due to the fact that ducks were wider in the cloth as woven than in the reed. He thought the point was of importance. He also suggested that increased weft strength would increase the cost of the cloth. He agreed that co-operation between all concerned, from the user to the spinner, was essential. He contended that the user would, in course of time, define what he wanted because he knew what he wanted.

Replying to Mr. Mills, the lecturer said that his main theme was the existence of economic barriers to doing what you want and what you knew ought to be done. Combination throughout the trade would provide a check upon waste and adulteration. He agreed that if the user knew exactly what was wanted he could take steps to secure it, but offered as an example of the ignorance of the maker-up the typical shirt which was so ill-designed as to wear out in certain parts long before the whole garment; seven-eights of a shirt had to be thrown away because one-eighth was worn out. This was an instance of a soundly-constructed fabric being made up incorrectly. He contended it was further proof of the need for co-operation.

Further contributions to the discussion were made by various members of the audience, dealing with the points raised by Mr. Mills and the lecturer. It was contended that price was the governing factor and that the manufacturer had to make cloth to a price knowing the goods so supplied were not suitable for their intended use. The starch collar was blamed for wearing out the shirt. Pre-laundering of a shirting length was recommended as a preventative measure against shrinkage. This shrinkage was also described as contraction and not shrinkage which, a speaker claimed, was a phenomenon peculiar to wool.

Proposing a vote of thanks to the lecturer, Mr. Mills said he feared the discussion had gone beyond the field covered by the lecture. He suggested that a further discussion might be arranged. The proposal was seconded and carried with acclamation. Mr. Meredith briefly responded.

NOTES AND NOTICES

Election of Council of the Institute

A list of the vacancies which arise on the Council of the Institute before the holding of the Annual General Meeting, fixed to take place at the Institute Headquarters, Manchester, on the 16th May next, was presented at the December meeting of the Council and approved for publication. Ten of the thirty elected members retire annually, but are eligible for re-election unless disqualified by reason of non-attendance. In due course, forms will be issued to members of the Institute for nomination of candidates for the 1934 vacancies. The following is a list of names of elected members, with the order of retirement—

1934	1935	1936
Barnes, H. C. (A.T.I.)	Beanland, R. J. H. (F.T.I.)	Barwick, F. W. (F.T.I.)
Davis, Wm.	Binns, H. (F.T.I.)	Boothman, W. T. (F.T.I.)
Lishman, W. W. L.	Greg, H. Gair	Bromiley, H. (F.T.I.)
Nisbet, H. (F.T.I.)	Read, J. (F.T.I.)	Crompton, W. B. (F.T.I.)
Stevenson, A. W. (F.T.I.)	Richardson, H.	Kershaw, S. (F.T.I.)
Strong, J. H. (F.T.I.)	Scott-Taggart, W. (F.T.I.)	Kershaw, W. (F.T.I.)
Vernon, W. (F.T.I.)	Slater, F. P.	Jaques, H.
Wilkinson, W. (F.T.I.)	Speakman, J. B. (F.T.I.)	Morton, W. E. (F.T.I.)
Wright, F. (F.T.I.)	Stott, T. S.	Watson, S. (F.T.I.)
———	Thompson, G. H. (F.T.I.)	Withers, J. C. (F.T.I.)

Annual General Meeting

The 24th Annual General Meeting of Members of the Institute has been fixed to take place at Headquarters, 16 St. Mary's Parsonage, Manchester, at 3 p.m. on Wednesday, the 16th May next, immediately subsequent to the ordinary Council Meeting which is to take place at 2 p.m. on the same day. At the Annual Meeting the report of Council, and the balance sheet and accounts for 1933 will be presented for acceptance. The result of the forthcoming ballot for Council election will be declared and a President will be elected for the ensuing year. At December meeting of Council, it was unanimously decided to invite Sir William Clare Lees to accept nomination for re-election, but, owing to pressure of calls upon his services, Sir William has intimated that he will be quite unable to continue to occupy the presidential chair.

Next Annual Conference

At the December meeting of the Council of the Institute, a decision was reached in favour of the selection of a textile industrial centre as the place for the holding of our Annual Conference in the latter part of Whit-week in the current year. In consequence of receipt of many representations from members that the policy associated with the last two conferences should be adhered to, the whole matter was reviewed at the January meeting of Council. It was decided—notice of motion having been tendered—to rescind the December resolution as to place selected and it was further agreed unanimously that the event shall take place at Grange-over-Sands, provided, of course, that satisfactory local arrangements can be effected. The Secretary was instructed to proceed without delay in the matter of securing accommodation. The Publications Committee and the Selection Committee of the Institute have already considered arrangements for contributions of Lectures or Papers. The general subject chosen for the occasion is that of "Conversion of Yarns into Fabrics", a field covered by Section III of the Journal Abstracts and by Section III of the Institute's Examination (Part II) in General Textile Technology. Members are asked to note the dates of this year's Conference—May 23rd to 27th, Wednesday to Saturday.

The Textile Institute

The title of our Institute appears to be remarkably attractive in the United States of America. In recent years, we have offered a respectful plea for the avoidance of duplication of the title, mainly with the object of prevention of confusion which might arise thereby, to the detriment of all interests involved. A few years ago, the Cotton Textile Institute of America was formed and we were unsuccessful in our overtures in favour of alternative title. More recently, the Silk Association of America Inc. announced the formation of a new organisation with the title of Textile Institute attached. In this instance, a communication from our Institute, pointing out the undesirability of duplication, received favourable consideration and we were graciously informed that an alternative title had been chosen. At the January meeting of our Finance and General Purposes Committee, the Secretary called attention to an article in *The Textile World* (*U.S.A*). advocating the promotion of an organisation to be called "The Textile Institute". The objects, as set forth in the article, appeared to be quite different from those of our own Institute. Under the circumstances, it is sincerely hoped that repetition of our title may be avoided. A letter addressed by the General Secretary to the Editor of the Journal mentioned was approved by the Committee and it is hoped and confidently expected that the plea will prove successful in this instance.

Lancashire Section—Social Gathering

It is many years since a social gathering was held in connection with the Lancashire Section of our Institute. The decision of the Section Committee to include such an event in the programme of the current session was therefore regarded as an innovation. A week or ten days before the holding of the Dinner-Dance at the Manchester Limited's rooms, the prospects of a good attendance were none too promising. Later, however, acceptances quickly reached satisfactory proportions, and the final attendance totalled 141 persons. Mr. T. E. Mitchell (Chairman of the Section Committee) presided over the dinner. The President (Sir William Clare Lees) was unable to attend but kindly contributed a donation towards the expenses. Messrs. H. S. Butterworth (Chairman of the Council of the British Cotton Industry Research Association), Dr. A. Coulthard (Institute of Chemistry), Mr. J. J. Butler (Federation of British Industries), Mr. H. N. Whalley (British Association of Managers of Textile Works), and Mr. John A. Cox (Director of Education, Bolton), attended as guests. In proposing the toast of "Our Guests", Mr. Mitchell warmly welcomed the visitors and Mr. Butterworth suitably responded. Dancing was indulged in until 11.30 p.m. and the proceedings proved most enjoyable. Small prizes were offered and awarded in the course of the evening. Messrs. Athey, Curtis, Nisbet, and Robinson, acted as stewards, whilst Mr. Frank Nasmith kindly served in the capacity of announcer.

Institute Membership

At the January meeting of the Council, the following were elected to Membership of the Institute—H. A. Hancock, B.Sc.(Lond.), Ministry of Agriculture, Spinning Division, Botanical Section, Giza, Egypt (Director of Experimental Spinning Station and Laboratory); H. Lloyd, 19 Godliman Street, London, E.C.4 (Manufacturers' Agent); G. Marshall, Aysgarth, 26 Longden Avenue, Crosland Moor, Huddersfield (Asst. Lecturer in Woollen Yarn Manufacture, Huddersfield Technical College); H. L. Parsons, B.Sc.(Lond.), Baxter Bros. Ltd., Research Department, Dundee (Head of Research Department)—transference of representative membership from N. Duncan; G. G. Pinder, Asa Lees & Co. Ltd., Soho Iron Works, Oldham (Director)—transference of representative membership from Henry Lawton; H. Raraty, 192 Northenden Road, Sale, Manchester (Sales representative, White, Child & Beney Ltd.)—transference of membership from H. G. Bolland; D. C. Snowden, 39 Kirkbrae, Galashiels, Scotland (Asst. Lecturer, Scottish Woollen Technical College); J. C. Thompson, "Straightacres", Eccleshill, Bradford (Textile Chemical Manufacturer). *Junior*—R. N. Williams, "Flawforth Lodge", Ruddington, Notts. (Sales and Technical Representative, J. H. Fenner & Co. Ltd.).

Honorary Membership—Ashley, Sir Percy, K.B.E., C.B.; Import Duties Advisory Committee, Caxton House (West Block), Tothill Street, London S.W.1.

INQUIRIES

Cotton Doubling

The undermentioned inquiry has been received by the Institute's Information Bureau and as it appeared to be of general interest is here printed. It is hoped that members who can do so will communicate to the Editor any information available either for transmission to the inquirer privately or for publication in a subsequent issue. The inquirer writes—

> "I should greatly appreciate your assistance on three points in connection with cotton doubling. I have spent some time searching the literature but cannot come across what I want. The points are—
>
> *Balanced Twist*—What is it and what use is it in practice ?
>
> *Maximum turns per inch in 2-fold yarns before the yarn becomes weaker.*
>
> *Maximum strength of doubled yarn*—Is it obtained by slow speed and heavy travellers ?

REVIEWS

"This Money Business." By Barnard Ellinger. Published by P. S. King & Son. (6s. net.)

The increasing disposition of economists to attribute greater importance to currency factors in the operation of the industrial system has in recent years had a twofold result: it has, in the first place, produced a large crop of highly complex currency theory and, in the second place, it has led to a veritable spate of books dealing with the working of the monetary system and designed to make clear to the ordinary man what is fundamentally an intricate matter. Most of the popular books on currency must be accounted failures, for they seek to combine with a description of monetary mechanism the theoretical considerations which the author favours and, in the nature of things, monetary theory cannot be simplified for general consumption.

Mr. Ellinger, however, has succeeded where so many others have failed, partly because of his great practical experience in many branches of the affairs of which he writes and partly because he has very wisely limited his task to an outline of the machinery of banking and finance and has not sought to combine with it a treatment of monetary theory. There could indeed be no better introduction to the whole question than that which is provided in this volume. The conscientious citizen who feels that his duty leads him to attempt to understand this branch of the economic system, which appears to have so many political implications, could have no better guide through the maze than Mr. Ellinger. The student could have no better introduction to a wider study of monetary problems for he will find here, succinctly described and aptly illustrated, a compressed picture of the working of the gold standard, of the operations of the money market, of the significance of central banks, and of the activities of deposit banks

In a final chapter Mr. Ellinger discusses the possible courses which were open to Great Britain after the abandonment of the Gold Standard in September 1931. As between those who advocate a return to the gold standard, either on the old or a new parity, and those who advocate a more deliberately controlled currency policy, he holds the balance evenly but he strongly emphasises the danger of a too precipitate return to a gold standard system, a view which subsequent events have proved to be correct. J.J.

Leinenweberei. Von F. Bühring, A. Schneider, M. Kaulfuss, and H. Schreiber. Technologie der Textilfasern. v. Band, 1 Teil, 3 Abt. Published by Verlag von Julius Springer, Berlin. (Price 32 RM.)

This volume on linen weaving, which is part of the series Technologie der Textilfasern, edited by Dr. R. O. Herzog, completes the section dealing with flax, the first volume of this section being devoted to fibre production and the second to spinning. Fabrics woven from flax cover a very wide range of weight and type of cloth and in consequence the methods involved in preparation and weaving vary quite appreciably in certain details. The editor has adopted the method of dividing the subject into three main sections, each one written by a specialist in that section. The first part of the book, 182 pages, deals with the weaving of light-goods and fancy cloths, and contains chapters describing the preparation of warp and weft for the loom, the general arrangement of the loom, the usual methods of shedding with tappet, dobby and jacquard, heddle and harness arrangements, the making of pattern cards for the fancy weaves, and cloth inspection, measuring, and cropping. Then comes an interesting and (to the English reader) more unusual chapter on general management and organisation of weaving, in which such points as space and power requirements, loom production and more-looms-per-weaver system, and costing are discussed. The inclusion finally of a short chapter on cloth finishing is certainly very useful and helps to complete the subject, but on the same basis one fails to see why brief details of cloth bleaching should not have been given. The second part of the volume, some twenty pages, is devoted to handkerchief weaving and contains a description of a loom with revolving shuttle box, as well as a short account of preparatory methods and weaving technique special to handkerchief manufacture. The third portion of the book, 50 pages, concerns the weaving of heavy cloths (such as comprise the bulk of the Scottish trade), and besides giving details of the preparatory and weaving methods contains a chapter on impregnation finishing processes, such as waterproofing, rubberising, and fireproofing. There is also brief mention of the ordinary mechanical finishing methods.

On the whole, the subject matter of the book is well balanced. In the chapter on jacquard shedding, the Verdol machine is given prominence presumably because of its more extensive use on the Continent than over here. As will be obvious from the fact that there are only 256 pages, and yet over 300 diagrams and photographs, the text is concise and by no means exhausts any branch of the subject. A great amount of the conciseness is obtained by confining attention to one or two typical mechanisms or processes in the discussion of each point, and the free use of diagrams and photographs and tables of figures. The whole result is that the continuity throughout the work is excellently maintained and the reader obtains a clear bird's-eye view of the subject, as well as adequate information on each point.

As mentioned above, the illustrations are very numerous and are excellently done, both line drawings and photographs, especially in Part I of the book. There are many tables, giving typical production figures for various processes, calculations of efficiency, speeds of running looms under various conditions, costing figures, etc., all of which add greatly to the practical aspect of the work. The book, like its companions in the series, is very well printed and bound.

H.B.

Handbuch der Azetylzellulosen. By Oskar Krausch. Published by J. F. Lehmann, Munich, 1933. (Pp. 274. Price 20 M.)

This book is really a bibliography of the literature on the preparation, properties, and applications of the cellulose acetates, and as such will be very useful to the research worker for the quick orientation of the work done to date on any particular problem connected with cellulose acetates. It contains a very useful list of trade names under which cellulose acetates are known in various countries as well as a very comprehensive list of patents. The descriptive matter, as one would expect from the nature of the book, is very meagre. R.G.

Zelluloseazetate und die anderen organischen Ester der Zellulose. By D. Krüger. Published by Theodor Steinkopff, Dresden and Leipzig, 1933. (Pp. 391. Price 20 R.M.)

As one would expect, the greater part of this book is devoted to cellulose acetate, only the last two chapters being allotted to the other esters. Moreover the adjective "organisch" apparently excludes cellulose nitrates and xanthates which receive no treatment at all. Only one chapter deals with the technical applications of cellulose acetate, acetate being given the most prominent, but by no means exclusive, place. The book is therefore only indirectly of textile interest, but it is the most complete account to date of the chemical and physical properties of these substances, and as such will form an extremely useful work of reference to the textile chemist.

R.G.

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PROCEEDINGS

London Section

Meeting at the Barrett Street Trade School, London, on Wednesday, 10th January 1934; Mr. Edward H. Symonds (President of the Fashions and Fabrics Bureau) in the chair.

SOME ECONOMIC PROBLEMS OF CHANGING FASHION

A paper on this subject was delivered by Professor Arnold Plant, of the London School of Economics, under the auspices of the London Section of the Institute.

The Chairman, introducing Professor Plant, said he held the view that fashion changes are the life-blood of modern manufacturing and distribution; without such changes there appeared to be no prospect of reducing unemployment. More frequent fashion changes tended to increase employment, to increase wages and thus contributed to a return to prosperity.

Professor Plant said that changing fashion was an extremely wide subject, implying changes in habits of consumption in the widest sense. It was to this aspect of fashion that the Chairman had referred in connection with the effect such changes had on employment. He could not concur entirely with this view as it was certainly not the case that public preferences must change if employment were to be maintained. Apart from short-period transfers, fashion changes need not effect the volume of employment. He suggested that annual changes in such things as motor cars, wireless sets, wallpapers, etc. were to some extent due to the effort to persuade people to dispose of their "obsolete models" and to replace them with the new. In investigating changes in consumer demands, which were of course changes in "taste", it was necessary to discriminate between spontaneous changes and those which were induced by changing conditions, such as a rise or fall in consumers' incomes.

The lecturer than referred to and quoted from a statistical investigation he had carried out relating to the expenditure by women on their dress and to the proportion spent on the various kinds of apparel. His figures related to about a thousand individuals whose incomes varied from a few pounds weekly up to perhaps £1,200 per annum. These figures indicated how dress expenditure was distributed over such groups as outdoor wear, dresses, millinery, stockings, and underclothing. He had found these figures very illuminating.

Continuing, Professor Plant said that there were those who protested at attempts to increase the rate of fashion changes; he felt that this was but an admission of incompetency. He suggested as a definition of fashion goods that they were midway between the exclusive article and the staple commodity. The vogue of to-day either became a staple commodity or disappeared The production of "fashion" goods was traced by the lecturer from the raw material to the "new models" released in time for acceptance (or rejection) for the coming season Some of these creations were short lived, whereas others were hailed as being the "mode" of the season and were copied in every civilised country. Skill had to be exercised in deciding which to copy and many expedients had been resorted to in order to ascertain the direction of the trend. Until some indication of the trend was forthcoming, larger scale production could not be embarked upon. He understood that interested parties sometimes made great efforts to influence this trend. They met frequently with an indifferent measure of success.

Behind the whole movement was the public's fancy, interference with which the lecturer strongly deprecated. In his opinion the public right of any individual to buy the goods of his choice was a fundamental of individual liberty, but its exercise was none the less bewildering to the scientist. He regarded this experimentation in creation, with a view to the establishment of a fashion, even if only of short duration, as of the greatest possible value. Out of it all there emerged some good which was permanent; some experience gained that was of use in the new endeavours being constantly made to utilise more and more fully the natural resources of the world. A survey of the nineteenth century fashions would indicate that they reflected the public taste of that period and he hoped that present-day trends revealed increasing fitness for purpose.

Professor Plant next referred to the lead in fashion determination so long held by Paris and suggested that this was not only due to public prejudice but also to the same causes as lead to the perpetuation of skill in some particular district, to the fact that in a congregation of experts progress would be more rapid and continuous than elsewhere. He deprecated strongly any legislative or administrative restrictions which hampered the producers of this country. If the latest of everything could not be secured in London, those who tried to create new vogues there would be unable to compete with other fashion centres.

The lecturer next referred to the seasonal character of this type of work. It seemed to him to require a floating population of workers who would go from place to place with the ebb and flow of demand. There was also the risk of the complete, or almost complete, elimination of a particular trade and the lecturer gave, as an instance, the substitution of the felt hat for the old "Covent Garden" production. Those not versatile enough to change over had suffered severely. The lecturer thought that the labour difficulties of seasonal trades would be increased in the future rather than diminished. He also referred to the effect of rapidly-changing or short-run fashions on machinery which would, unless extremely adaptable, soon become obsolete or be replaced by mass-production plant, if the vogue showed signs of becoming a staple line.

The question of piracy was then touched on by the lecturer, who said that he did not place much confidence on the proposals, mainly from the United States, to protect designs and styles in fashion goods by some legislation analagous to patenting mechanical inventions. The leaders in creating new styles were leaders because they kept ahead of their rivals; protection of their ideas meant little to them. Some of the most successful creators rather welcomed copying (and were paid for the privilege) and it was in this way that a vogue became established. On the other hand the producer of raw material was also interested in the change of fashion—witness the changes in demand for woollen and worsted goods and the reflection of such changes in the wool markets.

In conclusion Professor Plant referred to the conflicting proposals in regard to the production of fashion goods; there were those who advocated the widest possible range of styles and colours, in stockings for example, whereas others sought some degree of regimentation of the consumer; some limitation of the choice. He thought that a combination of the two proposals was probably the solution. At the one establishment the fullest possible choice would be displayed and the prices would be higher to meet the cost of production; at another establishment the range would be small and the prices lower. But there was a natural endeavour on the part of certain manufacturers and distributors to secure the higher prices with the lower costs by means of agreements to concentrate fashion trends to a smaller range. Such planning, at any rate in the textile industries, checked invention and experimentation and reduced the prospects of that section of the industry devoted to the creation of new fashions.

A discussion followed in which a number of speakers including the Chairman joined and to which replies were made by the lecturer. A vote of thanks to Professor Plant was heartily accorded on the motion of Mr. J. Howard (Fellow), seconded by Mr. J. D. Athey, General Secretary.

Meeting at 104 Newgate Street, London E.C.1, on Wednesday, 24th January 1934; Mr. G. A. Rushton in the chair.

THE RELATIONSHIP OF ART TO TECHNICAL TRAINING

The lecturer, Mr. S. I. Heiman, of the Leicester College of Arts and Crafts, said the title rather implied that the relationship between these two subjects had not been very happy or successful, and perhaps to some extent this was so. The artist-craftsman of pre-industrial revolution days combined art and industry in one mode of working, and under such conditions the question of relationships could not arise. The introduction of the machine made it necessary to consider these two factors separately and conjointly. Under the glamour of the machine, which produced things in quantity, the skill and sensitiveness of the craftsman atrophied and there appeared to be no impulse to consider beauty. Mass production became synonymous with ugliness-production and for a long time this satisfied most people. It was not that the machine was at fault or that increased production was not desirable, but that the specialist in design had been omitted from the organisations of industry.

Artists themselves, said the lecturer, were not entirely free from blame for the aforementioned state of affairs. Many of them had taken refuge in the so-called fine arts and cared little for machine-made products. Although we were still suffering from this era of sham art there were signs of the growth of better conditions. Perhaps the war had done something to engender a keener desire for a fuller life and art schools as well as prominent individuals had pressed for the recognition of the ability of the artist to assist industry. The action of the Government in founding an Art and Industrial Council was indeed heartening, though there were many difficulties, prejudices, and suspicions to be overcome

Mr. Heiman then analysed what he described as a vicious circle in the allocation of blame for the present impasse The manufacturer excused his poor products on the plea that the buyer was at fault. The buyer defended himself by saying he had to please the public and the public replied that the artists were poor. To this last charge, the artist replied that the manufacturers' demands had to be supplied. He held the view that the public had to choose from what was available and in the main its taste tended towards good and sane design. We could not escape the machine, he said, and we did not want to do so. But we did want things to be not only useful but also satisfying æsthetically; it costs little more to produce well-designed goods than ugly ones. Industry was suffering from the absence of the inspiring guidance of art. The co-operation of highly-qualified artists on the basis of attaching full significance to what they advocated, must be sought. The manufacturer might believe that good design was his salvation, but he was loath to entrust this salvation to the artist-specialist. Those countries noted for their industrial art were equally noted for allowing their artists to *lead* them in matters of design.

In many branches of industry, continued Mr. Heiman, there was need for operative-craftsmen as well as for creative designers. In olden days such a division did not really exist, but to-day the situation demanded this distinction. It was, in his opinion, profoundly important for all who worked in or were preparing to work in the artistic industries to imbibe as much art as possible; a course at an art school was therefore to be recommended. The lecturer referred to a scheme for co-operation between the art school and the factory described by Mr. Harold W. Sanderson* which he could commend as admirable so far as it went. He was urging that, however beneficial such a system might be for the operatives, experience showed that only the highly-gifted and widely-trained artist can be expected to make an appreciable improvement in the standard of industrial design. To do this effectively they must be given the opportunity to study the technology of the processes involved in the production of good and workable designs

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* *J. Royal Soc. Arts.*, 1933, **82** 183-199.

Dealing with the mode of training the artist in technical matters, the lecturer differentiated between the introduction of an artist directly into a factory, there to acquire a knowledge of the technical aspects of the industry, and the more general preference on the part of industrialists for the designer-artist to secure technical training before entering the factory. Such training can be given where the technical aspects of a subject can be taught in the art school itself, but where technical schools and art schools were separate establishments difficulties arose. He did not suggest that all technical matters could be taught in an art school, they were justifiably confined to the technical school and equally rightly art was taught in the art school. The problem was to secure co-operation between the two aspects of training for the artist-designer. He advocated teaching technology to the artist rather than art to the technologist—however revolutionary this might seem, especially in the northern counties. In his experience the art teacher readily applied himself to the study of technical matters and thus fitted himself for co-operation with the technical teacher.

In Leicester, said Mr. Heiman, during the last few years, a successful effort of co-operation had been made between the Colleges of Art and of Technology. The hosiery and the boot and shoe industries were the staple trades of the city. At first teachers from the Art College attended the Technical College for instruction. They did not obtain, obviously it was not necessary, so full a technical knowledge as the technical teacher, but sufficient to enable them to design intelligently for these industries and to guide their students in these matters. The College of Art had pursued the policy of finding students of the secondary school standard recommended by their school art teachers. They continued their training at the Art College on a course which included instruction at the Technical College in textile theory and factory methods. The lecturer gave fuller details of the courses provided and showed examples of fabrics designed by students in the Leicester College of Art and knitted in the College of Technology. Some, he said, had received prizes from the Textile Institute. At the end of their course, he stated, these students readily found posts in industrial organisations; indeed the demand was greater than the supply The success of the scheme led to its being applied to courses for those desirous of entering the shoe industry. Success had been achieved because of the hearty co-operation and goodwill of the staffs of the two colleges concerned.

In conclusion, Mr. Heiman referred briefly to the status and treatment of the artist-designer in industry. He knew of such short-sighted policy as expecting designers to clock-on with the operatives and to work amidst the noise and distraction of machines. The fitting of the artist into the factory was a new problem and to get the best out of the artist, the best conditions for doing so should be established. His power to create is a matter of inner development and will depend to a large degree upon the suitability of environment and on the encouragement that comes from due recognition of his work.

DISCUSSION

Mr. Woodman pointed out the difficulty that would arise in London if attempts were made to give art students factory experience. Possibly it could be met by ensuring a technical training for the teachers.

Mr. Howard said that he believed good designs in textiles came from those countries where the producer was a designer. He doubted whether anyone born in Oldham could ever produce designs such as those from Czechoslovakia. He doubted whether a factory with, say, 600 looms could afford to pay for an artist-designer.

A member suggested that Czechoslovakian designs which appeared to Mr. Howard as so superior to our own were not so regarded in the country of origin. It was simply that they were novel in this country. It would seem to be the case that designs did sell the cloths, and this would account for the imports of fabrics from Sweden, Czechoslovakia, France, Italy and Spain It was doubtful whether the buyer really did know what the public wanted; particularly the educated women members of the public.

Mr. Mills thought Lancashire and Yorkshire depended in the future to a real extent on securing improvement in quality of design. He agreed that there had been practically no co-operation between the art and technical colleges in the north. He referred to the employment by a Glasgow firm of the late Lewis F. Day, whose designs kept his firm in the running so long as he was with them.

Replying to the various speakers, Mr. Heiman said he thought favourably of Mr. Sanderson's scheme but questioned whether design in the industry was to be substantially improved by the method. He felt strongly that the artist-designer, particularly in respect of woven fabrics, must have an opportunity of studying the processes involved in manufacture. He pointed to the fact that in industries where real progress in design had been shown, this had been secured by artists and not from the craftsmen or technologists. It appeared to him suicidal on the part of an industry, to make a general statement that it had no need for artists. Designers were not to be merely copyists, and their work could only be competently judged by their peers.

A vote of thanks was proposed by Mr. Howard and seconded by Mr. W. H. Matthews. It was carried by acclamation and Mr. Heiman briefly replied.

Scottish Section

Meeting at the Scottish Woollen Technical College, Galashiels, on Thursday, 18th January 1934; the chair being occupied by Mr. J. Macpherson Brown.

THE OILING AND SCOURING OF WOOL

Mr. J. Dalby, of I.G. Dyestuffs A.-G., delivered an address on the above subject to members of the Scottish Section. It was his intention, he said, to consider the ideas underlying the processes of oiling and scouring and to suggest, if possible, how to improve the methods used. To carry out the processes of oiling and blending without a thought of the subsequent scouring might, and often did, result in extra costs in time, labour, and scouring materials. Any economy effected by employment of a cheap oil was thus negatived. He proposed to conside primarily the two processes of oiling and scouring in relation to each other and as applied to yarns and pieces.

The object of the oiling process, suggested Mr. Dalby, was to overcome friction between fibre and fibre and machine during carding and spinning; friction elimination reduced electrical phenomena and prevented flying of fibres. The oil was supplemented by the use of water and the amounts used varied with local conditions, upon which he was not going to enlarge. Turning to the kind of oil to employ, the lecturer pointed out that mineral oils by reason of the difficulty in removing them later, were generally avoided; that a few manufacturers used olive oil; but that the majority employed some quality or other of olein It was increasingly being applied as an emulsion. Goods containing olein could be scoured with soda alone, but those containing olive oil required the addition of soap to the scouring liquor.

The lecturer next referred to the two dangers, ever present, when olein was used, that of milling where not required and that of bleeding. In some cases neither fault mattered much, but where a lightweight open weave was desired, the use of much soda and the subsequently-formed soap was a definite drawback. It had been urged that "soap feeds wool" and while this was true, it was not necessarily desirable. Soap absorbed from a solution in which there was no alkali could not be washed out with water alone. It was also pointed out that soap left in wool might yield a good "handle" but would also probably give rise to a bad odour in storage. The problem of getting rid of the soap resolved itself into a question of the amount of alkali to be used or of finding an alternative. Also it must be noted that a hard water (unless a softening plant was used) emphasised the soap problem.

The lecturer, having summarised the matter so far given, proceeded to discuss suggestions for improving the efficiency of olein and of minimising its drawbacks. Four points seemed to him worth considering. Firstly the best way to apply the olein; this was generally conceded to be in the form of an emulsion. Secondly, how should olein be emulsified to get the best results; suitable emulsifiers were called for and those deemed best by the lecturer were described. Thirdly, how can soap be controlled in hard water to keep down lime soap scums—by the use of products of the sulphonated alcohol types. These substances scour like soaps, and are more or less unaffected by hard water or metallic salts, and certain of them prevent lime soap formation in hard water. Their use was described with particular reference to certain specified proprietary types. Fourthly, how can absorbed soap be removed from wool without the use of excess alkali; in soft water the problem does not really arise, but in hard water the precautions already mentioned were to be taken and the employment of certain scouring agents was recommended.

In conclusion Mr. Dalby considered the properties of an ideal oiling medium and suggested that those available to-day did not reach this ideal. Such a medium should be inert to fibre and machine; should lubricate efficiently; should not change in storage; should wash out easily in water alone with retention and without giving rise to scums. Goods containing such an ideal lubricant should dye without scouring; it should of itself act as a detergent. It would probably be better if it had no felting action. The lecturer thought it not fantastic to expect such an article would one day be found, and he indicated that a product was shortly to be marketed which went a long way towards this ideal. But works requirements were so varied that it might be doubted if any one product would meet them all. The search would not stop, however, and what was wanted was fuller co-operation between the manufacturer or processor and the research chemist or engineer.

Midlands Section

Meeting at the University College, Nottingham, on Thursday, 18th January 1934; Mr. T. Morley taking the chair.

SEWING COTTONS AND THEIR USES

Members of the Midlands Section heard a lecture on this occasion by Mr. A. Stoppard, of Messrs. J. W. Williams, Ltd., on the above-named subject. The Chairman welcomed the speaker in whose paper, he was sure, all present would be much interested.

Mr. Stoppard said he proposed to deal with sewing cotton from the time it left the doubling frame. Thereafter it is processed, and wound or spooled on to containers to suit customers' requirements. The choice of sewing cotton, he continued, should be governed by the character and quality of the garments to be sewn, and the ideal seam is that which retains all the features of the undisturbed fabric. But the type of sewing machines available and the twist in the thread, which should be spoken of as right or left twist, were also factors to be considered in choosing sewing cottons.

The lecturer next referred to the counts of sewing threads and stated that the one in principal use for dresses, outerwear, etc. was 60/3, with 16,800 yards to the pound, which gave greater length of sewing for the initial cost of the yarn. This recommendation, said Mr. Stoppard, should be regarded as a basis for calculations and should not always be rigidly adhered to. The table given below gives an indication of the counts supplied on domestic reels.

No. 10=	approximately	30–35/6	No. 36=	approximately	70/6
No. 16=	,,	40/6	No. 40=	,,	80/6
No. 20=	,,	45–50/6	No. 50=	,,	90/6
No. 24=	,,	50/6	No. 60=	,,	100/6
No. 30=	,,	60/6			

Mr. Stoppard next referred to the uses of sewing cottons and said they were well known and too numerous to be given in full. He proposed only to deal with defects and complaints with which the sewing cotton manufacturer had to deal. In turn he dealt with thick places due to faulty spinning or doubling; excessive wax; bleeding colours; needles too coarse for the fabric; winding defects; and mechanical troubles in the machines employed.

In conclusion the lecturer dealt with the processing of sewing threads, e.g. glazing, polishing, and dyeing; and the methods used in testing for which, he said, the most reliable were the tests made on the sewing machines themselves, as these were true working tests. If sewing cotton gave cause for complaint it had either been wrongly used; its qualities were poor; or the customer's estimate of its value was at fault. The lecturer suggested how these matters should be put right.

A vote of thanks to the lecturer was accorded heartily on the proposal of Mr. Thompson, seconded by Mr. Chamberlain.

Lancashire Section

Meeting at Bolton, on Friday, 26th January 1934; *Mr. R. Fletcher presiding.*

SOME TYPES OF YARNS USED AND FABRICS MADE IN THE KNITTING INDUSTRY

At a joint meeting of the Lancashire Section of the Textile Institute and the Bolton and District Managers' and Overlookers' Association, held at the Institute of the latter organisation, at Bolton, Mr. E. Millson Walker, A.T.I., contributed a paper on the above-named subject.

The Lecturer alluded to the spread of the ramifications of the hosiery and knitting industry in recent years. A good deal of misconception remained, however, as to the requirements of the industry in regard to yarns—the raw materials of which they are made, and the types of yarn employed. Partly due to research in relation to finishing and dyeing and to the production of synthetic filaments, but mainly to developments in machine construction, enormous strides had been achieved by the industry in the last 20 years. The manufacturer of knitted goods had invaded every branch of trade in wearing apparel. As a result of this movement, the manufacturer had had recourse to a much wider field of supplies of yarns. Whilst, generally speaking, hosiery yarns were of the soft "weft" twist type, particularly when used in relation to the production of underwear the material of which had to be of full and lofty handle, yet many garments now manufactured demanded yarns of higher twist and harder handle than were formerly employed.

After describing various machines employed in the industry and the types of yarns used in connection therewith, Mr. Walker referred at length to machines with Jacquard arrangements admitting of great variety of design in the fabric. Garments were cut out from the fabrics produced on these machines. In the circular-machine section of the industry there were many types for the making of rolls of fabric at high speed in plain and rib stitches and in fancy stitches.

Included in the circular machines was the machine making the interlock fabric so popular at the present time. This fabric, however, should not be confused with the "locknit" material produced on an entirely different machine—the warp loom.

Both in types of yarn and their counts, the range used to-day was enormous, whilst quite a lot of fancy yarn was also employed—curl, nep, and tinsel. One of the chief difficulties of the industry arose in consequence of irregularity and unlevelness of yarn—matters of great consequence remembering that a hosiery fabric consisted of rows of stitches or loops, each row being dependent on a row already formed.

Co-operation between spinners and manufacturers, based on mutual understanding and appreciation of each other's difficulties and requirements, was most important and if his effort that evening helped in the smallest measure in that direction he would be most gratified.

Questions were invited and Mr. Manton asked whether yarns which had followed the high-drafting process had been found quite satisfactory by the knitting industry.

The reply was that this was a matter under investigation and still subject to further experience. He saw no real reason for supposing that yarn so produced should create any real difficulty.

A number of specimens of knitted materials and garments were exhibited and examined with great interest and the lecturer discussed many features of the goods in relation to yarns employed.

A hearty vote of thanks terminated the proceedings, the Chairman expressing warm appreciation of the interchange of information which the meeting produced.

CORRIGENDUM

"FABRICS FOR INDUSTRIAL PURPOSES"

Two errors have been pointed out by the Author in our report of the above paper in this *Journal* for January 1934, pages P2–P4.

Page P3, line 9, after "50%" insert the word "above".

Page P3, line 30, for "28·5 to 24·25 per inch" read "38·5 to 34·25 per inch."

It is regretted that these errors should have arisen.—*Editor.*

NOTES AND NOTICES

Institute Annual Conference, 1934

Grange-over-Sands, the charming coastal resort of North Lancashire, has been selected as the venue for the next Conference of the Institute and the event is to take place in the latter part of Whit-week. Already, there are definite indications that the Conference will be exceptionally well attended. The general subject on which Papers or Lectures will be contributed is that comprised in Part 3 of the Abstracts Section of the *Journal* of the Institute—Conversion of Yarns into Fabrics. The response to invitations in regard to the contribution of Papers has been most gratifying and the measure of acceptance assures the provision of an attractive programme. There is obvious enthusiasm associated with the whole subject to be dealt with and discussed. The Grand Hotel at Grange, which has been chosen for headquarters, offers facilities which admit of all meetings and social gatherings being held on the premises. A Committee of the Institute has met and outlined the programme, and the record of minutes is now presented as giving a clear indication of the course of events.

Outline of Conference Programme

The minutes of the Conference Committee record the following decisions—

(1) The official period of the Conference be from Wednesday afternoon May 23rd to Friday afternoon May 25th inclusive, but mention should be made of possibilities of extension by private arrangement.

(2) The Programme to be issued in similar form to that of the previous year but type face of matter to be larger.

(3) Official Reception to take place on the Wednesday evening subsequent to ordinary dinner.

(4) Institute Dinner to be held on the Thursday evening. Local officials to be invited and all contributors of papers to be invited as guests; principals or managers of any works visited to be also invited. This dinner to be timed for assembly at 7.45 p.m. for 8 p.m., and toasts to be limited to two —"The King" and "Our Guests".

(5) The Mather Lecture to take place at 2 30 p.m. on the Friday.

(6) One excursion to be arranged, by motor-coach (starting at 2 p.m. prompt on Thursday), and possibly by lake steamer (Windermere), according to arrangements negotiated by the Secretary.

(7) Conference proceedings to commence at 9.30 a.m. on Thursday and Friday and carried forward with rigid adherence to a time-table, allowing 40 minutes for each contribution or 15 minutes for author and remainder for discussion and reply.

It was agreed that a preliminary card be issued to members and that various textile organisations be offered attendance facilities on the same terms as members. The Secretary was also authorised to issue a preliminary announcement to be sent out forthwith with ordinary postal communications from the Institute.

The Secretary reported on the arrangements completed for Headquarters Hotel (Grand Hotel), the inclusive charge for the official period of the Conference having been fixed at 36/– each person, this figure including afternoon tea on the Wednesday, all meals (including Institute Dinner), and accommodation up to and including luncheon on the Friday.

As previously, afternoon tea to be provided by the Institute on the Friday afternoon.

Endeavour to be made to issue final notice and attendance-form immediately after Easter-week.

Institute's Next Examination

In connection with applications for the Associateship of the Institute, the next examination for applicants referred thereto has been fixed to take place on June 13th and 20th next—Part I (Auxiliary Subjects) on the former and Part II (General Textile Technology) on the latter date. Last year, a total of 32 candidates presented themselves and this year about a similar number is anticipated whilst the Examination, as to Part II, will involve arrangements for simultaneous conduct in several centres and, in two or three instances, abroad.

National Certificates in Textiles

The Joint Committee of representatives of the Board of Education and of the Institute has now completed the work of preparation of a Scheme for the establishment of National Certificates in Textiles. It is anticipated that the Scheme will be submitted to the Board of Education and to the Council of the Institute at a fairly early date. In the first instance, however, the proposals will come before the March meeting of the Selection Committee of the Institute and be sent forward to Council with an accompanying report and other documents. If adopted by the

Council, the Scheme will be then submitted to the Board of Education as an approved plan. After the next meeting of the Selection Committee, it is expected that copies of the Scheme, and accompanying documents, will be provided for issue to members of the Council.

Institute Section Meetings

Meetings of Sections at which papers or lectures have been delivered appear, generally, to have been very well attended during the current session. The Irish Section has experienced a little difficulty in maintaining their programme owing to disappointment in engagements, but for Thursday, March 8th, Mr. W. A. Hanton, M.Sc.Tech., has kindly accepted an invitation to visit Belfast and again speak on "Recent Work on the Power Loom", a subject which he dealt with recently at a Lancashire Section meeting at Preston. The next Lancashire Section meeting is to take place at Manchester on March 14th, when Mr. H. Mason-Jones will contribute a paper on "The Theory and Practice of Calico-Printing"—a subject upon which a lecture has often previously been sought but found difficult to secure. On March 7th, Mr. J. Howard, F.T.I. (Chairman of the London Section Committee) is to give a paper at 104 Newgate Street, London, on "Waterproofing of Textile Fabrics". On March 21st next, at a meeting under the auspices of the London Section, a public lecture will be given at the Clothworkers' Hall, on "Origin and History of the Clothworkers' Company", by P. M. Evans Esq., C.B.E., M.A. Members of the Council of the Institute are specially invited to attend this lecture and arrangements are in progress.

Issue of Library Catalogue

The Committee in charge of this part of the Institute's work receives constant evidence upon two points. Firstly, more and more members realise that the Institute possesses a library—albeit far from the ideal in mind—and, having realised it, more and more frequently use it. On the other hand, there appears to be a considerable proportion of the total membership which actually is not aware that the facility exists and can be made use of. A catalogue of the library including all additions up to September 1933 is available for 6d. post free, and the rules for the borrowing of books, periodicals, catalogues, etc. are to be found therein. Additional accommodation for storing textile periodicals is being provided and the literature received at the Institute thereby will be more readily available.

Information Required

An inquiry has been received at the Institute for the name of any firm in a position to execute the spinning and weaving of silica glass wool. The Secretary would be pleased to communicate any useful reply to this inquiry.

Federation of Textile Societies

This year's Annual Meeting of the Federation is to take place on March 24th at Halifax, by invitation of the local Textile Society. The President, Mr. E. M. Roberts, of Bradford, anticipates a good attendance of delegates representing the 34 federated organisations. The programme is of considerable interest and a proposal will be brought before the Annual Meeting recommending the offer of a prize by the Federation in respect of a Paper contributed by a textile-society member during the 1934-1935 lecture session. At the Halifax meeting, the usual practice will be observed of the delivery of a lecture on the individual aspects of the district. Councillor T. W. Hanson will present a Paper on "The Growth of Halifax". Mr. G. H. Thompson, F.T.I., Oldham, is nominated for election as President of the Federation for 1934-1935.

REVIEWS

Pattern Design. By Lewis F. Day. Second edition, revised and enlarged by Amor Fenn. Published by B. T. Batsford Ltd., London. (300 illustrations, including two coloured plates. Price 10s. 6d. net.)

Lewis F. Day was one of the most distinguished decorative artists in Europe of the mid-Victorian period and his writings are known all the world over. With a reputation as a designer for textiles, wallpaper, stained glass, and pottery fully established, Day turned his attention to text-books. Here he became virtually a pioneer, being the first English designer of repute to place his knowledge and experience at the disposal of the student of design.

"Pattern Design" deals with the structural principles underlying the anatomy, planning, and evolution of ornament, a knowledge of which is essential for the decorative designer and incidental to any creative work whether painting, sculpture, or architectural. This book is of special value on the subject of textile design, the author having had an intimate connection with the fabric printing industry of Lancashire. From 1880 he was artistic director for Turnbull and Stockdales Ltd., and this well-known firm retained the exclusive use of his designs for furnishing fabrics until his death in 1909.

Mr. Amor Fenn, an artist fully in sympathy with Day and his work, whom the publishers wisely entrusted with the revision of "Pattern Design", has been successful in broadening its scope and bringing it up to date. A large number of illustrations have been added, of border and all-over patterns. Of the two coloured plates, one, Viennese Animal Designs, is most attractive. The additional chapter, No. XXI, deals with the development of pattern from the mid-Victorian period to the present time. The illustrations, arranged as far as possible in chronological order, include excellent examples of the work of Pugin, Talbert, Morris, Crane, Day, and Voysey, but it is surprising that the sixteen designs which follow of modernistic present-day patterns are all foreign, being typical examples of French, German, and Austrian work.

Nowadays there is a regrettable tendency to praise anything foreign in design. Good as these designs are, showing characteristic vitality and creative ability, it is unfortunate that some equally inspiring designs illustrating the trend of modern development in British productions are not included. The impression received of this comprehensive text-book is that design must be subservient to function, and that the keynote of success in decorative design depends to a large extent on practical knowledge and experience. E.R.D.

Die textilmicroskopischen Untersuchungen in der Praxis. By J. Klinger. Published by Verlag Sallmayersche Buchandlung, Wien, 1934. (Pp. 93, with 18 illustrations and 80 photomicrographs on art paper. R.M. 7·50.)

The author rightly points out that microscopical examination of textile materials is of the utmost importance in the study of textile problems. It provides a rapid and fairly simple means of identification, judgment of quality, and determination of the causes of faults. He also describes the field which he proposes to cover and the system or arrangement used in the book.

The book is divided into sections in which are described the examination of longitudinal sections, fabrics, and cross-sections. The applications of polarised light, dark ground and ultra-microscopy, projection and photography, are described, and there is a section containing a description of apparatus. Finally there is a series of 80 photomicrographs which illustrate the text.

The author has endeavoured to fulfil the promise of his preface by giving a systematic description of the preparation and methods of examination of textile materials and of the conclusions to be drawn therefrom. He has utilised only a small space and many things have had to be omitted. Many of the omissions are not unreasonable, and the absence of some hackneyed features is indeed welcome. From the title and preface one expects to find a general survey of the methods of examining all the more important fibres. One is rather surprised, therefore, to find that wool, silk, and cotton are passed over with a few lines, and information about linen, ramie, jute, etc. is conspicuous by its absence. In effect, the book is devoted to rayon in its various forms.

A short description is afforded of the identification of fibres by the appearance of their longitudinal and cross-sections, and by treatment with a few reagents. The text is illustrated by corresponding photographs, those of the cross-sections being generally very good compared with those of longitudinal sections. The discussion of the embedding, cutting, and manipulation of cross-sections is brief but fairly adequate. Equally brief is the description of the examination of faulty material, and further illustrations would have been welcome in this section. A number of excellent photographs illustrate the short section on cloth testing, and the effects of proper illumination are well shown.

Chapters are included which are very short surveys of the uses of polarised light, dark ground, and ultramicroscopy, projection, and photography. More detail is desirable in the description of the manipulation involved, particularly in the case of photomicrography.

The second part of the book contains a long chapter in which a suitable range of apparatus and its working is described in text and illustrations. This section is little more than a short catalogue of Messrs. Reichert's instruments. There follows a list of reagents and a description of suitable bench accommodation for apparatus. Five valuable pages are devoted to an index table of the details of the 80 photographs under each of which are found the same details. No page index is given to facilitate the finding of desired subjects.

One feels that the book is a useful addition to the textile student's bookshelf inasmuch as it affords a brief general survey of current practice in the microscopy of rayon. By applying the information and methods described the student would certainly be assisted in developing a sound technique. The book cannot, however, be considered important as a text-book of reference compared with the publications of Matthew, Beck, Preston, and several mentioned in the author's bibliography. P.B.

The Synthetic Dyestuffs and Intermediate Products. By Prof. J. F. Thorpe and Dr. R. P. Linstead. Seventh edition of "Cain and Thorpe". Published by Charles Griffin & Co. Ltd., London, 1933. (Pp. xv+472. Price, cloth, 30s.)
Eleven years have elapsed since the last edition of this well-known work was published; this followed quickly on the fifth, which was itself necessitated by the rapid exhaustion of the fourth edition. Great changes have occurred and much progress has been made in the field of synthetic colouring matters during this period. Consequently, with the collaboration of Dr. R. P. Linstead in the place of the late Dr. J. C. Cain, it has been essential to rewrite the subject-matter entirely, as well as to rearrange and extend it considerably. Thus, in the theoretical part, the section dealing with intermediate products occupies double the space allotted in the last edition, and is now an excellent, concise account of the principal types and more important compounds. The various sections on dyes have been expanded appropriately. For example, it has been necessary to subdivide the section on azo dyes and also the section on dyes of the anthraquinone series, special attention being given in the former case to "Ingrain" colours and mordant dyes, and in both cases dyes suitable for rayons being included. No doubt students will welcome particularly the clear accounts of the development of the quinoline colours of the cyanine class and of recent synthetic work on the anthocyanins. The rearrangement of the theoretical part is a convenience to the reader, as is also the frequent restatement of the older formulæ for dyes in terms of modern conceptions of valency, although, in general, the classical formulæ have been retained to avoid confusion. The practical part has been revised only in essential detail, but the chapter on general laboratory methods has been deleted, and the analytical part has been compressed into three appendices on the application, valuation, and analysis of dyes respectively.

The authors are to be congratulated on the success of their undertaking, for the result is outstanding both as a theoretical text-book and as a laboratory manual. All serious students of colour chemistry will read it with interest, whilst the generous use of formulæ will facilitate their understanding of the subject. The work is remarkably free from errors and in only a few cases has reference to recent advances in our knowledge of colouring matters been omitted. A student who has mastered the contents, however, will desire to consult the original literature for himself and should have no difficulty in doing so. F.M.R.

Stand und Aussichten des Baumwollbaus in der Sovet-Union. By Alexander Melkich. Published by Paul Parey, Berlin, 1933. (Pp. 109. Price 10 R.M.)
This brochure, as the title suggests, is the result of an investigation into the present position and prospects of cotton cultivation in the Soviet Union. The

desire of the Soviet Government to make itself independent of foreign cotton has led to a considerable increase in the cultivation of cotton in Russia which has produced technical and economic problems which are the subject of the present investigation. The whole question is thoroughly discussed in the first place from the point of view of the five-year-plan. Then the different ways in which the increased production has been achieved are described, and its effect on other branches of agriculture. The difficulties attendant on the introduction of new machinery and methods are outlined, and finally the economic problems are orientated. The information given appears to be without political bias and should therefore be very useful to anyone studying the position of cotton in the present state of world economics. R.G.

Rubber in Chemical Engineering. By H. P. Stevens and M. B. Donald. Issued by the Rubber Growers' Association Inc., 2, 3 and 4 Idol Lane, Eastcheap, London, E.C.3, 1933. (Pp. 55. Free.)

Manifold as are the uses which have already been found for rubber the possibilities seem to be unlimited. The present little book is devoted to an account of the ways in which rubber has helped to solve the problems of the chemical engineer, and treats of the use of rubber sheeting for making tanks acid proof, rubber paints and cements, rubber hose, vulcanite tubing and pumps, rubber bearings, filter presses, and floorings. The properties of rubber are accurately described with a special section on the resistance of rubber to chemicals. The authors have produced a very useful brochure which will be valued by any technologist. R.G.

Praktische Kunstseidenfärberei in Strang und Stück. By K. Götze and C. R. Merten. Published by Julius Springer, Berlin. (Pp. 144, 101 fig. R.M. 13.50.)

This book would have been more accurately described as an "Introduction to Practical Rayon Dyeing". Of 144 pages, only 23 relate directly to dyeing; the rest of the book is devoted to descriptions of the manufacture and properties of rayon yarns, and to accounts of preparatory and auxiliary processes such as desizing, scouring, bleaching, crêpeing, and delustring. The book is a curious mixture; in some places, many recipes and practical formulæ are given, and here the matter reads like an extract from a chemical manufacturer's catalogue. On the other hand, hints on the establishment of a dyeworks, including discussions on steam, electricity, and water supply, are dealt with in less than five pages. The treatment throughout is superficial and, in the reviewer's judgment, ill-balanced. Nevertheless, the book makes interesting reading and would probably be of some value to a newcomer to a dyeworks wishing to gain a general outline of the processes he might encounter. It cannot, however, be regarded as of real help to the practical dyer. The illustrations are well reproduced, and the general production and appearance of the book leaves little to be desired. H.H.

Practical Investigation of Dyestuffs on Fibres. By H. B. Holsboer and L. J. Lanzer. Published by the Hoogere Textiel School at Enschede, Holland.

A concise little book, containing much collected information regarding the investigation of various dyestuffs on all fibres, vegetable, animal, and artificial. The book will be useful in assisting merchants to estimate roughly the cost of dyeing patterns or samples which have been sent in for matching purposes, as very clear directions are given for identifying the types of colours used, even if it is not always possible to identify the actual name of the colour itself.

The book has a short introduction and consists of several chapters, treating the different groups of dyestuffs—Basic-, Acid-, Direct-, Mordant-, Ice Colours, Aniline, Sulphur-, Vat-, and Mineral Dyestuffs, their characteristics and properties, their reaction on various acids and on metals in the ash. It further contains shortly and clearly-outlined schemes for the investigation of dyestuffs on animal and vegetable fibres, methods of investigation, and an extensive Table for further indication of Vat Dyes by the characteristic colour of the Vat. Particularly useful are the chapters dealing with Groups of Dyestuffs individually. For each individual group a concise description is given of the character and properties, the method of application and investigation on the fibre. Remarks, of importance for the investigation of the dyestuffs, give the method of treatment of sample dyes. The difficulties connected with their identification is discussed and the solution to these difficulties given.

General remarks regarding the Application of Dyestuffs, explaining how the investigation is facilitated by knowledge of the different groups of dyestuffs, are given. The application of different groups of dyestuffs to cotton, linen, jute, artificial silk, and mixed fabrics of various kinds is discussed together with their fastness properties to light, rubbing, perspiration, etc. at the same time indicating the most suitable dyes for linings, flannels, velvets, shirtings, etc. A chapter is given which treats with the fastness of Dyestuffs, the degree of fastness on the fibres, the method of testing this degree of fastness by comparison with certain standards, at the same time giving those standards for several materials.

A useful survey is given at the end of the book of the operations applied during bleaching and dyeing of fibres, such as desizing, mercerising. Methods for diazotising and developing of ice colours are given, together with a discussion on the properties of oxidation-, natural, and mineral dyes. Each individual chapter gives clearly-outlined and useful information. The book is most suitable for students because of its comprehensive, yet concise, information, and may be considered an acquisition to existing literature on the subject. J.M.D.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

Intersecting Gill Box. Type 1 and 2. Platt Brothers & Co. Ltd., Oldham.
A descriptive catalogue of a new machine put on the market as a result of experiments conducted by the firm.

Kingston's Dollar/Price Conversion Tables. Published by Kingston's Translations Institute, Leadenhall Street, London. Price, 1s. 1d.
These tables which, in times of wide fluctuations of the dollar, should be useful, give the American (or Canadian) amounts from 1/32nd of a penny upwards at exchanges rising from $4.90 to $6.00 to the £.

Annual Report of the Department of Scientific and Industrial Research 1932-1933. Published by H.M. Stationery Office. (Price, 3s.; by post 3s. 3d. cmd. 4483.)
During the period covered by this report the Government grant of £1,000,000 for the encouragement of industrial research became exhausted. In large part this report summarises the results of the main experiment conducted with the aid of the Million Fund—the establishment of Industrial Research Associations.

American Society for Testing Materials: 1933 Index to Standards and Tentative Standards. Supplied free from the offices of the Society, 260 S. Broad Street, Philadelphia, U.S.A.
This index, covering 689 standards, should be a convenience in finding specifications and as a guide to all interested in test methods.

National Provincial Bank. Review of a Century of Establishment 1833-1933. Compiled by Hartley Withers and issued by the Bank, 15 Bishopsgate, London, E.C.2.
This is an example of bookmaking par excellence and the producers are to be complimented upon it from that point of view. But its contents commended themselves as highly—a record of joint-stock banking, its early failures and ultimate success; the birth and growth of the National Provincial Bank; and the union with other banking concerns are all dealt with in a satisfactory manner.

The Romance of Rayon. By Arnold H. Hard. 1933. Published by Whittaker & Robinson Ltd., Manchester. (76 pp. Price, 5s. net.)
The author claims that this small book is an attempt to preserve the stories of its pioneers given to him during his connection with the textile press. The attempt was certainly justified and a very valuable and interesting record has been compiled.

Yorkshire Council for Further Education.
Memorandum of proposals for the training of designers of woven fabrics in design and colour.

Federation Lainiere Internationale. Bulletin No. 9. October 1933.
This issue contains regulations for the conditioning of wool as approved by the Special Commission at Budapest, October 1933. A translation into English is also available.

Journal of the East India Association. Published by the Association, Westminster Chambers, Victoria Street, London S.W. Vol. 25, No. 1, January 1934.
Contains an article by S. S. Hammersley, M.P., on "The Lancashire Textile Mission to India", and a discussion on the foregoing paper.

Industrial Health Research Board. "Incentives in Repetitive Work: a Practical Experiment in a Factory." By S. Wyatt, assisted by L. Frost and F. G. L. Stock. Printed and published by H.M. Stationery Office. (Price, 1s. 3d. net.)
Describes an investigation which set out to study the reactions of a number of individual workers, to varying kinds and conditions of work, in particular to the effects of the varying incentives embodied in different wage-systems. Presents the first "close-up" psychological picture of a group of operatives engaged in repetition work, which has been taken in this country.

The Continental Directory of Cotton Spinners and Manufacturers 1933-1934 (15s. net) **and The British and Dominion Textile Industry (excluding Lancashire and Yorkshire) 1934** (12s. 6d. net). Published by John Worrall Ltd., Oldham.
By oversight, it is some years since a copy of Worrall s Continental Directory reached this library and the contrast between the two volumes now compared is most marked; it emphasises the great improvement made by this firm in the production of its Directories. The British and Dominion Directory maintains the standard achieved and falls into its useful place alongside the other volumes issued by Messrs. Worrall. We still live in hope of the inclusion of maps in these Directories.

GENERAL ITEMS AND REPORTS

THE EFFECTS OF LAUNDERING PROCESSES ON FABRICS*

By R. E. V. Hampson, D.Sc., Director of the British Launderers' Research Association, to the Blackburn Textile Society on 1st December 1933

Your syllabus shows that an appreciable portion of your time is devoted to the discussion of faults and problems in the various textile operations. It, therefore, seems fitting that I may have an opportunity of presenting a consideration of the effects which laundering may have on fabrics and of the features of fabric manufacture which may have an influence on its after life in the laundry. Our work is not complete if in making an article we have paid insufficient attention to the purpose to which it must be put and to the period of wear which may be expected of it. Such a consideration is of vital importance at any time, but when one hears the word "Economy" on all sides it would be short-sighted to imagine that true economy is possible without such attention. The public requires good wearing value for money.

Before I can raise any criticism or suggest any general lines of improvement it is essential that I should describe the various methods of present-day laundering, and explain the attitude of the launderer towards the fabrics he handles. Laundering is a cleansing treatment which has to be repeated frequently during the life of an article; and thus differs from the finishing of a fabric. The launderer must be prepared to give similar treatments time and time again to the same fabric, in such a manner that he causes the least possible harm. Furthermore, he must consider not only the cost of his treatments and their effects upon the fabric, but the speed at which they may be given. In the laundry the material handled is not in one continuous piece. It consists of a miscellaneous collection of fabrics, different in actual material, in size, in shape or appearance, in the dyes carried, and in coming from different makers. This diversity has not only its problems in the matter of washing but also in the methods of finishing. Flatwork can, for instance, be finished by comparatively simple mechanical means up to a point; even then sheets, table linen, etc. are of different sizes and cannot be folded by machine. Other classes of articles of more elaborate make-up may be finished by mechanical means with difficulty, perhaps only in part, and at the end of the list come those articles for which hand finishing only is possible.

These essential features of laundering work render classification of the various articles an absolute necessity. Methods naturally differ, but under ordinary conditions classification is based on the following principles. First,

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there is classification based upon the material of which an article is made, or upon some other predominant characteristic, *e.g.* that it is dyed. Secondly, there is classification based upon the type of article. In practice it is common to employ both methods, and to classify in groups such as cotton sheets, cotton pillowslips, linen damask, coloured shirts, woollen socks, silk stockings, and stiff collars. Classification can also be carried out if circumstances warrant, upon the condition of soiling. Sub-classification of this character may be superimposed upon the ordinary grouping; for instance, heavily-soiled sheets, etc. may be separated from those of a lightly-soiled character, and heavily-stained table linen may be treated differently from hotel work in which soiling may have hardly taken place at all.

For each special classification there follows its process, designed specially for the treatment of the articles in the group. Laundering treatments are supposed not to be of a very scientific character, but to be based more on the results of experience than any definite experimental foundation. The Laundry industry is young as an organised industry, and scientific development in the laundry is as yet only in its infancy, yet every year sees laundry work become more of a science and less of an art, using methods and processes based upon sound foundations.

The specialised treatment for white work would include sheets, body linen, pillowslips, towels and, with minor modifications, table linen, collars, etc. and, as I must confine myself to principles, this particular classification can be regarded as typical. Processes for other classifications such as woollens, coloured work. silks, etc., are based upon exactly the same principles, although wide modifications may be imposed by the nature of the articles.

The function of any washing process is that complete separation of dirt and fabric must be effected and the article must be returned to its owner in a clean condition; it is necessary, therefore, to employ means which prevent the dirt being redeposited once it has been detached from the fabric, and finally to remove it completely There are, therefore, at least three features which must be observed if good washing is to result—(1) the ability to detach dirt from the fabric; (2) the ability to suspend the dirt detached and prevent its redeposition; and (3) adequate means of removal of liquor from the machine in which the operation is performed.

A laundry washing machine consists of an outer cylinder capable of holding any necessary washing liquor and being fed by water and steam supplies from the outside. Within is a perforated cylinder, or cage, of brass, of monel metal, or stainless steel, in which is placed the work to be washed. This cylinder revolves within the outer cylinder and by means of lifters or baffles, imparts motion to the fabrics, lifting and dropping them in such a way that adequate cleansing becomes possible. Revolutions of the cage are first in one direction then in the other. While it is in action, the washing liquor in the outside case is also disturbed, and by its flowing through the perforations of the cage, complete and continuous mixing of it with the fabrics to be washed can be effected. The washing liquid may be heated to any desired temperature by means of steam, it may be run at any desired depth, and soap and alkali may be added to it in any desired proportions; finally it may be run out from the machine at the end of any stage of washing by means of the valve at the bottom of the case.

Washing processes are carried out in a series of stages each of which is designed to perform a certain definite function. In Table I four such stages are shown.

The *first stage* consists of practically nothing else but a rinse with cold water, but it has the effect of removing the large particles of dirt which are loosely adherent to the fabrics and also of dissolving any soiling material capable of being removed in this manner. The process is very short and the water is run at a high level or "dip"; and thus the amount of mechanical agitation that the goods receive is small.

The *second stage* of the process is the first real wash. The work still contains much soiling matter, of all types, and in particles of all sizes. Much of it might be rendered insoluble or "set" by being raised to a high temperature and therefore the first wash is always run only just warm. The main function of this wash is to handle that comparatively large quantity of soiling matter which is removable from the fabrics without much difficulty. It is, therefore, not necessary to provide conditions under which the greatest power of removing the dirt from the work is obtained; this would be inadvisable, for it is under precisely those conditions that a detergent liquor has the least power of suspending dirt and preventing it from re-settling. The power of the liquid for suspending the dirt that is readily removed from the fabrics should be at its maximum. This condition is given by using a comparatively large amount of soap and a small proportion of alkali. There is also required plenty of such liquor in order that the fraction of it that is necessarily retained by the wet work when the machine is emptied may be small. By this means a larger proportion of the suspended dirt is removed from the machine than would otherwise be possible. From the comparatively high "dip" necessary for this purpose the mechanical motion the work receives is slight, and this reduces the power that the wash has for removing dirt from the fabrics. Since this power is not the function of this particular wash, there is no disadvantage, but the corresponding advantage that the work is not unduly worn by excessive motion is considerable.

Table I—The Stages of a Washing Process

Stages	Functions		
Breakdown	Large particle dirt only removed, load wetted out	No suspending power ...	No soap; slight alkalinity
		Small mechanical agitation	High "dip"
		Low temperature	90–100° F.
Wash 1	Large proportion of dirt easily removed	Good suspending liquor	Soap; low alkalinity
		Small agitation Large amount of liquor run to drain	Fairly high "dip"
		Cool temperature	110–120° F.
Wash 2	Dirt more difficult to remove	Suspending liquor not so important, better dirt remover wanted	Soap; higher alkalinity
		More agitation	Lower "dip"
		Increased temperature	140° F.
Wash 3	More resistant dirt	Excellent dirt remover	Soap and highest alkalinity
		Most mechanical motion	Low "dip"
		High temperature	212° F.

In the *third stage*, *i.e.* the second wash, conditions are not the same. The work contains some proportion of dirt, carried over from the first wash suspended in adherent soap liquor, and a larger amount of smaller-particle soiling matter that first-wash conditions would never remove. The problem is, therefore, to maintain suspending power as much as possible, but to secure production of better dirt-removing power. A soap solution of higher alkalinity is used and an increased temperature assists.

The lowering of the "dip" somewhat, provides also increased rubbing of the work and therefore better removal of dirt, but it must not be carried too far, otherwise an insufficient proportion of what is still a dirty liquor will be removed at the end of the wash. The alkalinity must be adjusted to provide increased dirt-removing power without loss of suspending power; and the "dip" must be so chosen that, while sufficient free water is present to enable a large proportion of dirty liquor to be removed from the machine, there is less than in the first wash in order that the mechanical side of the removing of dirt from the fabrics may have increased effect. The point at which these factors are adjusted depends largely upon the class of work that is being washed, but the general needs of the average laundry are, however, met by the use of roughly equal weights of soap and soda and a "dip" some two-thirds that of the first wash.

In some cases it is necessary to give four washes in all; Table I, however, shows only the general case where three are necessary. In the last wash the factors affecting the removal of dirt from the fabrics must be at their maximum; it is this part of the process which cleanses the fabrics from small traces of greasy matter, oils, etc., which are most difficult to remove. Their total quantity is, however, small and in consequence a detergent liquor at high temperature and of high alkalinity may be properly used; its low suspending power is of no moment provided that the previous washes were successful.

On the mechanical side of washing the use of low "dips" increases the rubbing etc. that the work receives. This information was obtained from the study of a specially-constructed machine whose end was of glass in order that the actual motion of the work could be observed under different conditions. In this machine changes could readily be made in the number of baffles, and in their design and spacing around the cage. Figs. 1 and 2 are views of the machine in which, with the exception of the quantity of liquid in the machine, the conditions are identical. Where the quantity of liquor is small, *i.e.* where the "dip" is low, the fabric piles itself up considerably when the machine is revolving, then falls almost vertically with a heavy impact upon the almost dry metal of the cage. In the second case the effects are different. First the load is much more open—it takes up more room in the cage, although it is actually the same load as before, and then after the piling up process it rolls and slides, eventually to fall more or less into a cushion of liquor within the cage. There is also a rolling motion within the loosely-packed load. This explains the assumption that the lower the "dip" is, the more severe is the mechanical treatment that the load receives.

Another factor that influences the severity of the rubbing action is the density of the load in the machine, and further experiments have shown that, within limits, it is the smaller loads which undergo the most severe treatment in this respect. The large loads experience very slight mechanical motion, rather that of rolling than of falling. This gives us a second method of controlling the degree of mechanical action, for although it is of course impracticable to alter the size of the load during the run of one process, it is possible to use larger loads where the work is comparatively clean, taking smaller batches of more heavily-soiled work in order to obtain those conditions of rubbing more suitable for the removal of highly-resistant dirt particles in large amounts. The varying conditions necessary in the actual washing apply to some extent also to the rinsing which follows, and it is unnecessary to enter into details of this part of the process. The whole of the process is summarised in the form of a diagram, Fig. 3. The shading on the diagram represents, by its intensity, the different degrees of soiling that the work shows at various stages of the process and the curves across it show respectively the changes made in temperature and alkali-soap ratio to produce the desirable effects in dirt-removing power and dirt-suspending power. The necessary changes in "dip" are not shown and no reference is made to the length of time required for each stage; but control of the time is, however, a very important matter. A further interesting fact recorded upon this diagram is that the temperatures employed are sufficient to bring about pasteurisation in the third stage, while complete sterilisation takes place in the fourth.

To obtain the necessary conditions there are many factors to control, and the modern machine is fitted with instruments to record temperatures, quantities of water, etc. An instrument exists which controls all the details of the process; adding the correct amounts of soap and soda and correct quantities of water; controlling the steam heating of the machine so that the proper temperature is obtained; opening and shutting the draining valve; all strictly to time, the whole process lasting about an hour and a quarter

The laundry process must be rapid. There are few laundries which can give longer than 1½ hours, average time, for a process since, if the work is a long time in the wash-house, the sorting room becomes jammed while the finishing departments are standing idle. The difference between the finishing problem and that of the launderer is that the finisher's treatment of fabrics must be given once and once only; time is not of prime urgency. The launderer has to treat fabrics over and over again during their lives, his processes must be rapid and yet he is expected to cleanse the fabrics of not only ordinary dirt but of greases and stains of all conceivable kinds. Furthermore in most cases he does not even know what those soiling matters are.

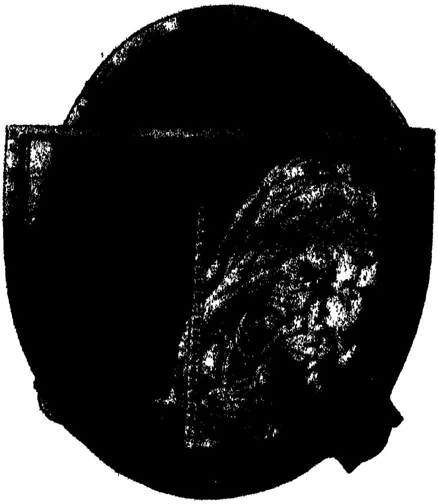


Fig. 1—Showing the motion of the work in a washing machine running at a low "dip".

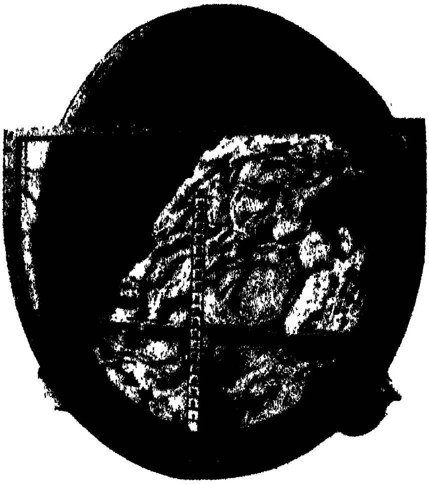


Fig. 2—Showing the motion of the work in a washing machine at a higher "dip".

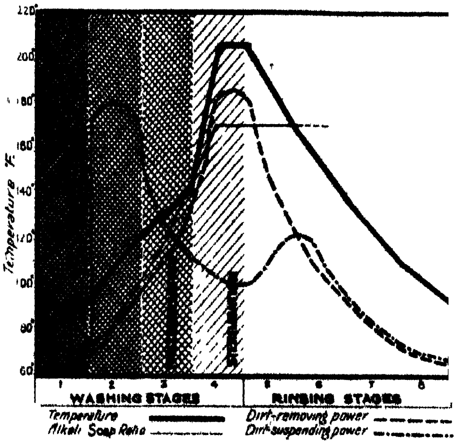


Fig. 3

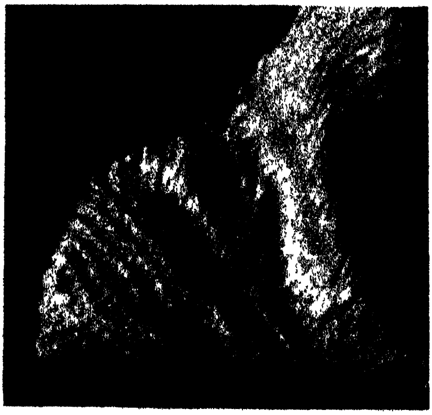
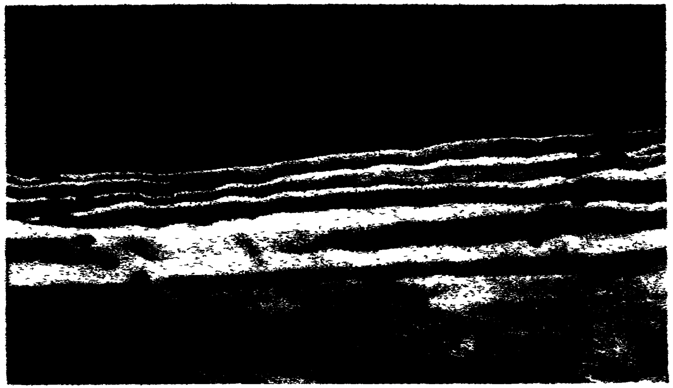


Fig. 4—Showing the floats of a damask weave standing out as loops when the fabric is folded.

FIG. 5—Showing the creases which develop in a new piece of fabric when it is wetted and allowed to dry un-ironed.



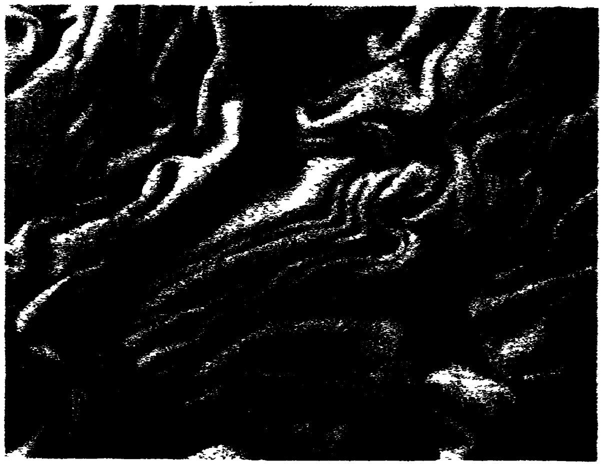


FIG. 6

Here is a comparison of a typical laundry process of cleansing and bleaching with the normal cotton finishing process. The launderer dare not begin his processes with hot water for fear of "setting" certain stains, and his breakdown lasts for only about five minutes. Compare this with the bleachers' preliminary grey soaking treatment which is followed, I believe, with a lime-boil under pressure. No single part of the laundry processes corresponds at all to that, but the launderer would like to be able to use processes lasting for six to ten hours at temperatures of between 230–290° F. His chances of avoiding re-wash, *i.e.* work sent back because it was not clean, would be considerably higher, but would the fabrics last as well as they do now ? The launderer does not normally use a sour except for some special purpose, but when he does he would not risk the use of even dilute hydrochloric acid of 2% strength in the laundry. In his case it would have to be a weak acetic acid sour of, say, 1 or 2 per cent.

It is with the lye-boil that the best comparison can be drawn. Assuming that the bleacher uses caustic soda to the extent of 2% on the weight of the goods and water corresponding to about 70 gallons per 100 lb., the strength of his solution is about 200 grains of caustic soda per gallon. In this solution the cotton is boiled for 8 hours at a temperature of about 250° F. (*i.e.* 10–15 lb./sq. in.) or if using soda-ash instead of caustic soda, it is understood that as much as 400 grains per gallon may be used and temperatures as high even as 290° F. for four or five hours. In laundry processes the highest alkalinity ever reached in normal cases is 150–200 grains of soda ash in the boil or hottest wash of the process. It runs for an average of 15 minutes and is fortunate to attain a temperature of 210° F. To "boil" ordinary white work for longer than 20 minutes would be considered very drastic and damaging to the work. In the laundry the work is being tumbled about during that time, but even then I do not consider such a process at all drastic compared with the bleachers' process.

In bleaching, solutions of bleaching powder having strengths of between ½° and 2° Tw. are used; translated into laundry units they correspond to between 98 and 390 grains of available chlorine per gallon. The bleaching treatment is of course cold and lasts for some hours. Compare that treatment with laundry bleaching, where treatments at five grains of chlorine at 140° F. for ten minutes is the safe upper limit for bleaching In textile bleaching and finishing there exist factors which make those treatments milder than they appear. The lye-boil is carried out in the absence of air and with the work at rest in the cold; the laundry processes are put through with the work in motion and in the presence of air, and with the work warm. These conditions arise from the need for expedition, and are a compromise between long treatments and those which, possibly very rapid, might endanger the strength or the life of the fabrics.

The following are indications of directions in which modifications are necessary in treating work in other laundry groups; *e.g.* dyed goods. There is great need for careful sub-classification in order that dyes of the same degree of fastness may be washed together or that dyes of approximately the same colour may be washed together. These sub-classifications are usually made on the basis of long experience. One general principle, however, is adopted, that of washing a batch of work by a process suitable for the most fugitive colour it contains. The arrangements the launderer makes for the washing of the various batches, in the main, consist of reducing temperatures considerably, of reducing alkalinity (possibly no alkali at all), and of using special neutral soaps of free rinsing habit, suitable for the low temperatures employed. Time too may be shortened.

Another manner in which to reduce the severity of washing is the reduction of the mechanical side of the process. This may be done by making changes in the "dip" at which the process runs. Such changes do not always give sufficiently wide variations. For woollens, for instance, only very little and gentle mechanical action is permissible, owing to the liability of woollen fabrics, even nowadays, to felt. In handling table linen, mechanical action must be gentle and of short duration in order that the floats of the yarns may not be broken and general fluffiness of the fabrics produced. Fig. 4 shows the effect produced when a weave containing floats is folded as it must be in a washing machine. The yarn across the float is entirely unprotected against any wear that it may receive from rubbing. In order to obtain this gentleness of treatment, the Research Association of the Laundry Industry has designed a special driving gear for attachment to the ordinary washing machine by means of which interruption of the normal motion of the machine takes place at regular intervals and for variable periods.

After washing and rinsing, all goods are treated in a hydro-extractor to remove the bulk of the water that they contain. It completely supersedes mangling and wringing, and there can be little doubt that it provides a method of partial drying much less damaging to the fabrics than those older methods. I do not say that a hydro cannot produce tears; it can easily tear an article placed across it, because in this position the ends of the fabric are pulling different ways and a burst is probable. This effect is, however, due solely to the carelessness of the operator of the machine.

Work leaves the hydro still damp; it usually contains half as much water as the dry weight of the work, and this has to be removed by the processes of drying and ironing. Drying in the laundry cannot easily be done out of doors owing to uncertainties of weather, but it is far more expensive to the launderer to dry inside.

The conventional method of drying in a laundry is in the use of a drying room. It contains clips upon which garments can be hung before being moved into the chamber in which there is a strong draught of hot air. Work takes some 20 minutes or half an hour to dry in these drying rooms. A modified drying machine is the "tumbler", which again dries by a strong draught of heated air, but in this case the work is in a slowly revolving wire basket. This machine is more expensive to run than the ordinary drying room but definitely gives a softer finish.

A large amount of work passes straight from the hydro to the various ironing machines. Among these are primarily the machines for flatwork. For sheets and large articles not requiring much polish, the multiple roll ironer is used. A six-roll machine is often worked by a team of ten girls and can iron up to 350 sheets per hour. For a better finish, for example, the best quality linen damask which has been starched, a single roller machine known as a decoudun is principally used. The pressure on the work is not more than 1 or 2 pounds per square inch, and is delivered by the soft padding surrounding the roller. It is, however, enough to produce a good polish upon table linen.

Shaped garments such as shirts and body linen are usually finished on presses which act by pressing the work between a steam-heated chest and a padded bed or "buck", as it is called, and the pressure between the two is nowadays provided pneumatically. A species of power-driven "hand-iron" is often used, and this, with its very heavy iron moving backwards and forwards and round and round at the will of the operator and at the lightest touch of her hand, is a very flexible tool.

Modern laundry methods are scientifically designed with two objects in view; (1) to carry out the particular part of the whole cleansing and finishing process in the best possible and most expeditious way and (2) to do it with the least harmful effect upon the fabrics as possible. Although efforts are made to maintain the best conditions, it will have been observed that there are many ways in which those conditions may be missed. All workers are human beings, and as such can and do make mistakes which may be serious in their results. In the classifying department there is a great responsibility on the classifier. A good sorter takes her job very seriously and possibly consults others before making a decision. Can you blame her entirely if she makes a mistake with an article which she has never seen before, and of whose history, make-up, and manufacture from fibre to fabric, she can have no direct knowledge ? Mistakes cannot always be avoided however good the launderer's knowledge is; he cannot, under present conditions, hope to have detailed knowledge of the materials, construction, dye and finish of every fabric that comes to his hands.

Most launderers nowadays will readily acknowledge mistakes. Lack of the detailed knowledge is definitely not his fault, especially as the industry is to-day providing classes of instruction at which the operators can learn the general principles of fabric manufacture, make-up, and finish. There are only two other parties concerned in the matter; the manufacturers of fabrics, including spinners, weavers, bleachers, dyers, and finishers, and the public which buys the goods marketed. Neither of these can be blamed; the former works his processes to produce what will satisfy a demand, and the public buys what is marketed because it likes the look of it. One is always ready to lay the blame on any other and no two have yet really seen that what is required is co-operation.

The first example wherein co-operation appears necessary is the terry-towel fabric. The chief trouble experienced with these articles is that their loops very easily pull out and in consequence customers complain to this effect. There is practically no chance, apart from an accident, during the laundering of these fabrics of their becoming caught in such a way as to pull the loops out. Further, the towel in its passage through the laundry is in a wet condition for most of the time, and it is submitted that the loops would pull less easily then than when the towel is dry. Given equal conditions of yarns per inch in the fabrics, the pile loops on the three-pick terry are not so tightly held as those of the four, five, or six-pick fabrics. It would seem therefore that the three-pick terry towel is not best suited for a long life. Yet out of about 300 bath towels, collected in North London and sent to a particular laundry, 97% of them were three-pick terrys, 2·4% were four pick, there were no five-pick terrys, and only one woven on a six-pick basis (0·6%). The main reason for this preponderance of the three-pick weave appears to be its cheapness, but an initial cheapness like this is often a false economy, since unless the ground work yarns of a three-pick towel are reasonably hard spun and the ends or picks to the inch are many, the pile loops must rapidly pull out in wear, causing dissatisfaction to the customer and unnecessary trouble to the launderer.

Another class of fabric that often gives trouble is that of sheeting of a very unbalanced weave. A particular case of this can be given in detail by an analysis of the fabric. The tensile strength per inch strip was 12–15 lb. warp-ways and 35–40 lb. weft-ways. It was a regular 2/2 twill fabric, ends and picks being roughly 45 to the inch. Both yarns were single, the warp having a count of 30's and the weft of 9's, and both yarns appeared to be normal, the calculated twists being therefore 17 to the inch, warps, and 8 to the inch, wefts. Examination also showed that neither yarn was of good quality; irregularities appearing in each. Such a fabric cannot be expected to stand up to normal conditions of wear and washing.

Another difficulty experienced is that of shrinkage, not particularly shrinkage of woollens, but of cotton and other fabrics. Take the case of engineers' blue overalls or dungarees. Being myself an engineer I have constantly noticed that dungarees are exceedingly difficult to put on after they have been washed once or twice, and even more difficult to take off. The shrinkage arises from complete lack of co-operation, everybody should know that engineers' overalls want a lot of washing, and the washing process for them is not one using low temperatures and gentle treatment; they require definitely vigorous treatment including a boil to de-grease them—in some cases it practically needs a lye-boil. There appears to be no reason why these garments should not be sold ready to stand up to the treatment that they must inevitably receive, more particularly that the material should be pre-shrunk properly before it is sold.

The case of some serviettes presents another instance; after washing they presented an appearance which was very fluffy and hairy, and not at all like good damask with its smooth polished appearance. The washing process was perfectly normal and chemical tests of the fabric both before and after washing showed that the laundering had produced no chemical damage by overbleaching, etc. This was confirmed by the fact that the sewing cotton in the articles was also undamaged. The hairiness was found to be easily reproducible by macerating the fabric in distilled water (which could in itself have no deleterious effect upon any fabric designed to be washed), and it proved to be due to the fact that the weft yarns were so soft spun as to come apart readily with the slightest degree of mechanical rubbing. As it is not possible to wash articles clean without some mechanical motion, the fabric should have been designed to withstand a reasonable amount.

The formation of lines of wear along the edges, principally the selvedges of flatwork is a matter that gives trouble. A piece of new fabric, if wetted and allowed to dry unstretched, shows creases which nearly always run more or less parallel to the selvedge (Fig 5). I have wondered whether these creases, which come again in the same places after an ironing and second wetting, are possibly due to the fabric having been processed in rope form during its finishing. Now, such a fabric in laundering, will of course crease itself in the washing machine and presumably in these definite more or less parallel lines whenever it is free to do so.

Fig. 6 shows a close-up view of a load of work in the glass-ended machine. It will be seen that the edges of the folds get more rubbing than the rest of the fabric. The line along the edge of the fold, therefore, receives very slightly more wear than the other parts of the fabric and this slight extra wear further disposes the fabric to fold along the same lines next time it is washed. That it does do so is shown by Fig. 7 which shows the condition of a piece of fabric that was found to have this predisposition to fold along the lines between the ink spots. The photograph was taken after it had been deliberately smoothed out by ironing and after it had been folded in lines at right angles to the lines between the spots. The effect of a run in the washing machine had been to unfold the creases artificially put into the fabric and to allow those to which the fabric was naturally disposed to re-develop, with the result shown. The process of wear along these lines continues as launderings successively follow one another and the result is shown by the last photograph (Fig. 8). The lines of wear are now practically through the fabric whose edges will now rapidly come apart in strips. An investigation of the reason for the original formation of the creases would be welcome and this is again a matter in which co-operation would be of great assistance.

There are two other examples of matters that cause considerable difficulty. Of late years there has been a fashion for the use of tablecloths more or less coloured all over, probably more than one colour being used, either in woven patterns or else in printed designs. Spilled tea stains a cloth, coloured or not, and the laundry is expected to remove such stains. If they are light stains which have not aged for any length of time their removal is not a problem of much difficulty since a fresh tea-stain of light density will almost wash out without special treatment. But not all tea-stains (or for that matter stains of any other kind) are light and fresh when these cloths come for washing, and there is bound to be chemical treatment, that of using a bleach, for their removal. To withstand a bleaching treatment the dyes themselves must be of a type unaffected by an oxidising bleach; at present by no means all of them are so and it is again here that we ask for some assistance. To make and sell a tablecloth with no thought of the processes it is bound to be subjected to in its life of use, is a procedure that must necessarily give dissatisfaction; at present the launderer is the object of the dissatisfaction.

Many goods are given a souring treatment at a late stage of their manufacture, and an acid is not very readily rinsed from, let us say, a cotton fabric If the acid used is a non-volatile acid—for example, sulphuric acid—the slightest trace of it that may be left in the fabric does not pass off in the final calendering or pressing treatment that the article may receive before being marketed. It remains in the fabric, and since nearly all the water has been evaporated by that final pressing etc. it is present in a concentrated form. We have recently come across this state of affairs in a large batch of sheets which, immediately after purchase, were stored for some time unused and unwashed. The sheeting was seriously tendered, not so that the owner would notice it, but sufficiently so for the laundry treatment to develop holes and tears. We examined unwashed sheets of the batch; they showed definite presence of sulphuric acid. Those washed with soap and alkali of course did not, since the acid was naturally all removed in the process. I think those sheets should have been tested for acidity before being finally passed out; the test is a very simple one.

The launderer recognises his responsibilities as conservator of the fabrics that in Lancashire, and in other parts, are made for the public use. Every endeavour is made to treat those goods in the best possible way in order to carry out two almost contradictory ideas; to remove any amount of any kind of soiling matter and to do it without damage to the fabrics. On the other hand mistakes are made and launderers wish to be honest about them and to take their medicine when called upon to do so. We desire in short to be completely fair-minded, recognising also other people's difficulties and those of the public. But the laundry is not always wrong, as many of the cases given show, and it is here that we ask for co-operation. If the textile industries and the launderers can co-operate in seeing that fabrics sold are designed for and receive proper washing processes, the eternal triangle of the manufacturer, the purchaser, and the launderer can become a united and contented trinity.

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PROCEEDINGS

Yorkshire Section

Meeting at the Midland Hotel, Bradford, on Thursday, 30th November, 1933;
Mr. T. H. Robinson in the chair.

SULPHUR IN WOOL

By A. T. King B.Sc., F.I.C.,
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INTRODUCTION

It is only in recent years that serious attention has been given to the scientific study of fleece production and wool structure. Such scientific assistance as has been given in the past to the producer in improving fleece character has been mainly from the study of nutritional and genetic influences, particularly the former, in their more general effects upon the whole animal, within the limits suited to the locality.

Nor did the wool itself, as an end-product of animal metabolism, interest the bio-chemist as do the chemical constituents of, and changes in, living tissues; its biochemical synthesis and even its composition remained obscure, and its significance as a special problem in animal metabolism unrealised.

Further, the study of the principles underlying the follicle mechanism producing it attracted no attention from the chemical side, and remained in the hands of the histologist.

Indeed, although the nutritional aspect gradually became more definitely focussed upon the fleece production itself, with a growing acceptance of the view that nutritional as distinct from genetic factors can influence, within limits, the nature of the wool supply, it was not until reliable sulphur determinations provided some measure of chemical comparison of different wools that any real insight was afforded into the biological aspect of the problem.

To establish characteristic differences in general composition between wool types is a difficult problem, even more so than between wool and the other animal fibres and integumentary structures designated as of scleroprotein composition. All these proteins are distinguished by the considerable percentage of sulphur they contain, which, as is well known, serves as a convenient qualitative test. There was, however, no disposition to regard its presence as of any unusual significance, qualitatively or quantitatively, either as to biological origin or chemical constitution; yet among the several directions of recent research into these problems, that concerning sulphur content, which was the first to be systematically investigated, has undoubtedly been one of the most fruitful.

THE SULPHUR CONTENT OF DIFFERENT WOOLS

The proof of variable sulphur content in wool[1] (see for example the values quoted in Table I), and the substantially sulphur-free nature ascribed to the medulla[2], afforded the first evidence calling attention to the fundamental importance of sulphur in wool *growth.*[3] It is of interest to note that the indirect proof advanced by Barritt and King (1927) of the absence of sulphur in the medulla has recently received strong support in a paper by Lloyd and Marriott,[4] who have actually isolated and analysed the medulla of goat hair, and found it to be sulphur-free. It is not surprising, therefore, that with varying kempiness or medullation different percentages of sulphur are found.

Table I

Wool		Per cent. on Dry Weight	
		Ash	Sulphur
Australian merino	A. 4	0·22	3·91
,, ,,	A. 6	0·125	3·46
,, ,,	F. 85	0·14	3·46
,, ,,	F. 86	0·12 0·08	4·11
South African merino	C. 39	0·18	3·53
,, ,, ,,		0·36	3·94
,, ,, ,,		0·14 0·09	3·67
Lincoln (La Concordia)		0·315 0·28	4·01
Lincoln (English)		0·34 0·39	3·10
Romney Corriedale		—	3·22
Welsh Mountain	S. 64	0·14	4·01
Devon Lamb		0·27 0·21	3·34

In non-medullated wools also, considerable variation in sulphur content is shown. Scale and cortex, as well as being different histologically, are known to be chemically different in one respect at all events—tyrosine is present in the cortex but not in the scale—and there may possibly be different percentages of sulphur in the scale and cortex portions of the fibre. Thus varying proportions of scale might possibly occasion variation in mean sulphur content, though this has been negatived in the case of human hair.[5] Nor would it be likely that sufficient variation in the proportion of scale could occur to account for the marked variation in sulphur content observed in fibres of similar type, and indeed along the length of individual staples. Recent analyses of Cheviot wools[6] grown at the Rowett Research Institute, before and after certain experimental diets, give overwhelming proof of earlier published conclusions. In some cases a very slight pull sufficed to separate the staple at the "break" occasioned by the change of diet, so that the change in sulphur content could easily be followed. In one case the two portions of the staple grown on the same animal contained 3·31% sulphur and 3·82% of sulphur respectively.

It is quite clear, therefore, that apart from possible variations due to varying proportions of scale, cortex, and medulla, the cortex itself, which forms the main bulk of the fibre, and may be regarded as the typical keratin substance, is of variable sulphur content.

The Form of Sulphur in Wool

The analytical results are from wools carefully purified from inorganic forms of sulphur, e.g. sulphate, and refer to sulphur present entirely in organic form. It has, of course, long been known that cystine

$$(COOH-CH(NH_2)-CH_2-S-S-CH_2-CH(NH_2)-COOH),$$

the only sulphur-containing acid in the group of amino acids recognised as essential in animal metabolism, is the characteristic sulphur-containing compound derived from keratins, and the fact that the sulphur is accounted for in its practical entirety as cystine[7,8] has focussed attention upon this particular form of sulphur in nutrition. It will be appreciated that the sulphur content may be taken as a measure of the cystine content, at least so far as freshly-formed keratin is concerned.

Another sulphur-containing acid, methionine (γ-methyl-thiol α-amino-butyric acid) is present in small quantity, but Barritt's recent determinations[9] indicate that not more than 0·1% of sulphur is present in this form, so that it does not appreciably affect this discussion.

The nutritional aspect has already been reviewed at some length[9] and need only be briefly indicated, but the quantitative side of the problem is obviously of first importance to the wool grower, and I may briefly recall the extensive work by the late Dr. Brailsford Robertson.[10] This was based on two assumptions—the constant content of sulphur existing wholly as cystine in wool, and the "essential" rôle of cystine in animal metabolism. The former must be regarded as erroneous, but this did not invalidate the general grounds for nutritional investigation provided by the latter. If cystine cannot be synthesised by animals from other sources of sulphur, their cystine requirements must be obtained by them pre-formed in the diet. Hence Robertson's conclusion that "it is not the withdrawal of sulphur from the soil which is the crucial factor in wool production, but the provision of cystine by the pasture". Thus "the carrying capacity of any country for sheep may very probably be determined by the capacity of its pasture plants to produce cystine". This led him to visualise the possibility of cystine deficiency, as a serious menace to the Australian wool-growing interests.

Much discussion and experiment has followed as to the food cystine—wool cystine balance sheet, culminating in the startling conclusion of Rimington and Bekker[11] that the sheep grows more wool than corresponds to the cystine content of its food intake, and must therefore, contrary to the orthodox biochemical view,. actually synthesise cystine from other forms of sulphur in its food. The lack of definite data as to food consumption, and especially of reliable methods for estimating cystine in plant foodstuffs, precludes at present any definite conclusion on this interesting question and its implications[12].

Investigation has also followed on the effect of cystine feeding on the yield and composition of wool and hair, which it may be said has in the main confirmed the view of Barritt and King that the *composition* as well as the *yield* of wool is subject to nutritional influences. To quote from a recent paper by Smuts, Mitchell, and Hamilton[13]—"The cystine-deficient diet (in rats) produces a hair deficient in cystine; the effect is removed by adding cystine to the diet until the cystine deficiency has been satisfied". It is of interest that these workers found in the coat from cystine-deficient diets, abnormally medullated hair, and ascribed to this the lower sulphur content assuming it to be relatively poor in sulphur as has already been proved for wool medulla.

Their investigation also emphasised the importance, not only of cystine sufficiency, but of general amino acid sufficiency. Thus with cystine deficiency only, a lower yield of wool with low percentage of sulphur would result; if cystine sufficient, but, for example, lysine deficient, a "normal" sulphur content with low yield would be expected; and general protein sufficiency will favour increased yield.

The protein level is, however, by no means the only factor in wool production. Important results are expected shortly from Rowett Institute experiments concerning the carbohydrate level. There are also factors more "catalytic" in character, for example, iodine sufficiency, and especially iron sufficiency, which has been shown by Aston,[14] and Rigg,[15], to cause striking improvement in fleece production in normally iron-deficient sheep-growing areas in New Zealand.

All such influences must eventually be reflected in the extent of cystine incorporation (in conjunction with the fleece yield), and in this connection King and Nichols[16] have advanced the hypothesis of a "cystine* gradient" in the nutrient stream supplying the papilla. Briefly, the assumption is that the cystine concentration in the blood stream, and its rate of flow, will influence the availability of cystine (1) to the whole follicle according to its shape and disposition of its seating in the dermal tissues, and (2) to the various parts of the individual follicle.

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* Not actually cystine but a cysteine derivative, presumably glutathione.

Histologically there is an orderly sequence in the development by keratinisation of inner root sheath, cuticle, cortex, and medulla. This must have a chemical significance. The order of formation implies the same order of availability of building materials from the blood stream. The inner root sheath, the first to be formed, is of course eventually shed. We have not yet had sufficient material available for quantitative analysis, but qualitative tests react strongly for cystine, and this ordinarily lost follicle product will have to be taken into account before a correct food cystine—fleece cystine balance sheet can be arrived at. Of the fibre proper, the cell stream originating closest to the nutrient stream is that of the fibre cuticle. The last and most remote from the nutrient stream is that of the medulla, where in view of its sulphur-free nature, the nutrient stream is on this gradient hypothesis, regarded as exhausted of cystine.

This view is in harmony with the recognised existence of growth gradients in the animal body. The mathematical explanation of spiral growth in horns developed by D'Arcy Thompson from growth gradient premises has been suggested by Nichols,[17] viewing wool growth as horn growth in miniature, as the simplest and also the most plausible theory of spiral growth in wool so far offered. We cannot on this view expect to find a perfectly straight fibre growing anywhere except perhaps at the tip of the tail or along the locus of convergence of opposing growth gradients. The more rapid cell proliferation at the follicle region most favourably disposed to the growth gradient is further aggravated in the Merino by its club-shaped follicle. It is a reasonable inference that the "cystinisation" or keratinisation is similarly preferential. Such considerations would introduce still further factors causing, and increasing the degree of, variability in sulphur content of wool keratin.

THE VARIABLE AMINO ACID MAKE-UP OF PROTEINS

The suggestion of variability in the amino acid make-up of proteins has been regarded in some quarters as biochemical heresy, and Robertson and Marston[10] strongly maintained the view of constant cystine content in wool keratin. But that there is a great difference in sulphur content between human hair and wool is now recognised. Why not between different types of wool ?

Rimington has drawn attention in a private note to the fact that evidence similar to that accumulated on the variable composition of wool keratin is available in the case of caseinogen, proving that the conception of such a protein as a fixed and unvarying chemical entity is in need of modification. Published analyses show, for example, in different specimens of cow's milk only 0·9 to 1·9% alanine, 1·0 to 7·9% valine, and 10·7 to 15·9% glutamic acid. The figures for caseinogens from goat's milk and human milk show corresponding divergencies. Admittedly there is much greater probability of experimental error in such determinations (excluding perhaps glutamic acid) than in sulphur (indirect cystine) determinations, which are capable of great precision.

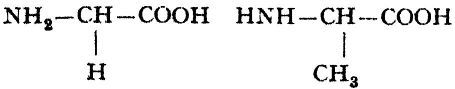
It is in fact in the sulphur-bearing proteins that variability might be deemed especially likely to occur, in view of the above interpretations of cystine incorporation. At all events acceptance of it, and its significant consequences, make the subject of much wider interest than could the doctrine of constant amino acid composition.

It is thus helpful for the moment to regard the main protein chains of all follicle products as evidencing a standard type of biological activity, and the cystinisation of these chains in different degree as the main chemical basis of the different variations of wool and hair in which this biological activity is manifested.

Nor, if the gradient theory be pursued, can we exclude the possibility of *variation in the proportion of other amino acids.*

It will be appreciated that the "backbone" of polypeptide molecules, which is a repeat of the α-amino acid residue $-NH-\overset{|}{C}H-CO-$ is the only type of backbone which *can* be formed from the known acids (some 14 in number and without exception α-amino acids) derived from keratin, *whatever their proportions and whatever the order of their incorporation in the main chain.* Variation in their proportion and order of linking only affects the relative numbers of the different substituent groups, and their distribution, regular or otherwise, along the backbone; the backbone itself remains the same.

In natural silk, which is derived mainly from the relatively simple acids glycine and alanine,



$$NH_2-\underset{H}{\underset{|}{CH}}-COOH \qquad HNH-\underset{CH_3}{\underset{|}{CH}}-COOH$$

glycine alanine

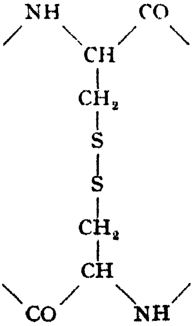
the "backbone" characteristic predominates. Consequently, Astbury's X-ray photograph of this protein approaches more nearly the clearness of those of inorganic crystals than does that of stretched wool, where the pattern of the same repeating α-amino acid residue is "blurred" by the great variety of substituent groups, and, on the above reasoning, their variable proportion and order in the long chain.

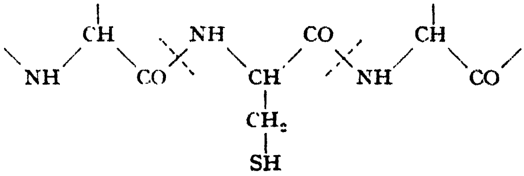
Such molecular chains in keratin would be in rough analogy with "mixed crystal" formation as represented in the natural silicates, for example, angite (Mg, Ca, Fe^{11}, Mh^{11}) Sio$_3$. This variable contribution of different metals to give one atomic proportion is consistent with the diffused X-ray pattern of asbestos.

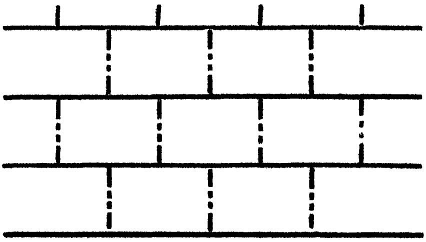
The conception that the follicle can utilise the amino acid complements according to its type, and in fluctuating proportions according to exigencies of diet and so on, at least provides a plausible explanation of the variations recognised in the trade in dyeing properties, etc. between wools from different sources, without undermining the "backbone" characteristic common to all of them.

DISPOSITION OF CYSTINE IN KERATIN STRUCTURE

As Astbury and Speakman have pointed out,[18] cystine being a "double amino acid" is capable of supplying a residue to each of two neighbouring main chains of the keratin molecule

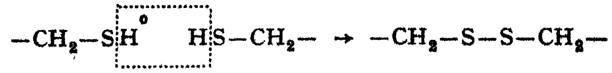






It should be noted, however, that it is unlikely that these are "ready-made" rungs which fit themselves into the structure. The sulphur group is not present as *cystine* in the blood stream, but in the reduced form as a cysteine derivative. Thus these amino acid residues become condensed into the body of the main chains just as the rest of the amino acid residues, the side chain it leaves being $-CH_2-SH$.

It is the subsequent linking of one such side chain with another sufficiently near to it on an adjacent long chain, by oxidation



$$-CH_2-S\boxed{H \overset{O}{} H}S-CH_2- \rightarrow -CH_2-S-S-CH_2-$$

which may be regarded as the basis of cystinisation or true keratinisation, as distinguished from general "cornification" in non-sulphur proteins.

The link across adjacent chains would also tend, not to be at right angles to the main chains, but to be disposed obliquely—the histological formation and the obliquity of the keratinisation zone would provide for this. Also the variable incorporation of the sulphur nucleus takes on a new meaning here. Just as it is probable that the sulphur content of a sample is the mean of differing values in individual fibres and even in different parts of the same fibre, so these rungs are not necessarily evenly spaced but accommodated according to fluctuating biological conditions. Thus the chance of a bridge being exactly at right angles to the main chain direction, or even of the bridges lying obliquely parallel between two main chains would be small. They could lie at various angles to the fibre direction, depending on the proximity of available cysteine groups. The sum total of their resistance to stretching will be considerable, but with some it will be greater than with others; those which happen to lie at right angles, or nearly so, will offer relatively little resistance, and there should be considerable variation in the stability of these linkages.

Though we cannot argue with certainty, the salt-forming linkages or peptide linkages from the glutamic and arginine residues will probably be disposed more regularly, which would drive us to the conclusion that the cystine links play a predominant part in resisting elongation of the main chains.

The chemical significance of this grouping is also achieving prominence. Unpublished experiments with Barritt showed that after long insolation, which only caused a 5% loss of sulphur, but a greatly weakened fibre, it was no longer possible to isolate cystine from the products of hydrolysis. Clearly the lability of this grouping is an important factor in fibre property. Much of the chemistry of the behaviour of organic disulphides towards oxidising and reducing agents is already known, and the application of such to the study of this disulphide link in keratin now being pursued by Dr. Speakman,[18] should throw much needed light on the technical effects of oxidising and reducing agents in processing.

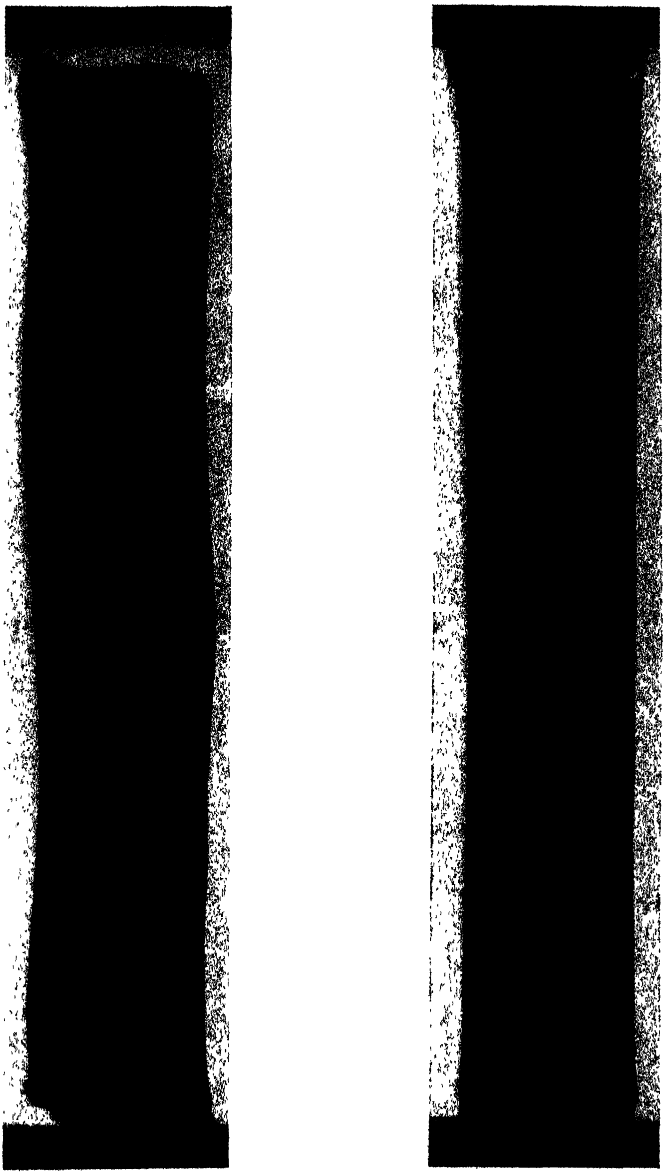
Regarding physical properties, there are obvious difficulties in the way of getting direct evidence of the influence of different sulphur contents independently of other variables.

The relation to spinning power, for example, is difficult to test from the practical spinning standpoint. There is some indirect evidence, however, assuming the correlation of good spinning with circularity of fibre cross-section shown by Barker and Burgess[19], from the comparison of fibre circularity with sulphur content. Sidey[20] found that so far as the limited number of wools examined could show, the superior wools, both from the trade judgment and the contour figures, were those of higher sulphur content.

As to the expected influence of sulphur content on fibre strength and elasticity, no very conclusive evidence is yet available. Some preliminary measurements by Rossouw, in fact, indicated little, if any, superiority of strength with higher sulphur content. It is more likely that differences would be shown when stretching is carried out in water, and such experiments would be welcome.

Another property in which differences might be revealed, which has not yet been studied, from this particular aspect, is the resistance to torsion, and a comparison of the behaviour in this respect of wools of different sulphur content would be valuable.

Certainly in one direction—the spirality of hosiery webbing—interesting evidence, which has some bearing on both the physical and the chemical rôle of cystine, is available.

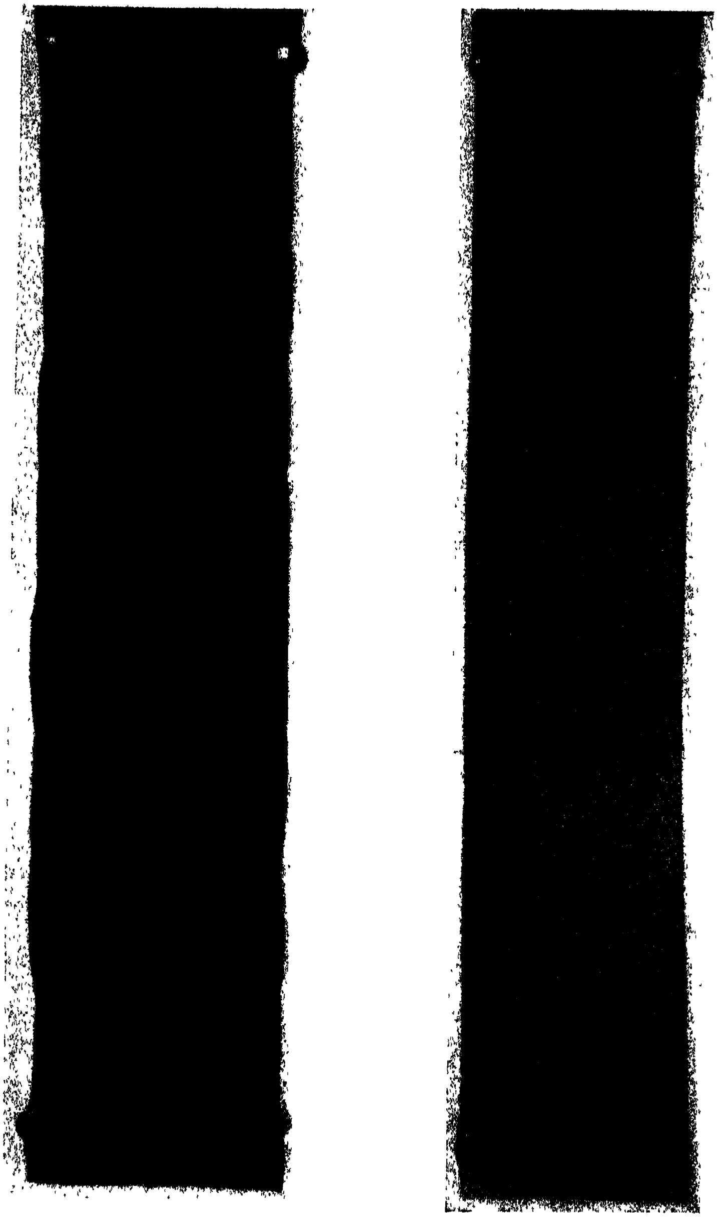


(a) (b)

FIG. 1

Removal of Spirality

(By courtesy of the Wool Industries Research Association, Leeds)



(a)
Before treatment

(b)
After treatment

FIG. 2

Removal of Spirality

(*By courtesy of the Wool Industries Research Association, Leeds*)

Yarn twist naturally involves individual fibre twist, and a tendency of the yarn to "snarl" on slackening if the twist is considerable, and invariably to untwist itself if the end is left free, unless the yarn has been set. If only temporarily set it does not untwist if kept dry, but at once does so on wetting. Nor does ordinary steaming of the yarn on bobbins entirely eliminate the untwisting effect. When the latter occurs it will tend to distort the resulting fabric. Such distortion is very commonly encountered in hosiery. In a plain stretch, the wales, or needle lines, instead of being at right angles to the rows of stitches, are inclined from the vertical, to left or right according to the direction of twist, and in degree proportionate to the degree of twist in the yarn, as shown by Davis, Edwards, and Stanbury[21]. It has been called the spirality effect, owing to this appearance in tubular webbing.

The effect is sometimes shown in woven pieces, in their failure to tear at right angles to the list, but the relatively compact structure resists more or less completely the tendency of the yarn to untwist after being secured in position in the woven piece.

Theoretically this effect must exist, potentially at least, with all single yarns except in the case of twistless yarns, but with two-fold yarns the effect can be balanced out by opposite twist of the component singles.

When the effect is not too severe it may be temporarily corrected during steam pressing by forcing the webbing to lie straight on the board as it enters the press, but it largely reverts to its corkscrew formation on subsequent scouring. It occurred to me, in view of observations with Mr. E. Hill that complete removal of cockling, etc. from crossbred worsted cloth could be produced by cold sodium sulphide solutions—in effect a "cold crabbing" process—that spirality in webbing should disappear under such treatment. Mr. Hill accordingly subjected a series of knitted patterns showing spirality effects to the action of sodium sulphide under controlled conditions, with successful results. No pulling into shape or stretching is necessary. The fabric automatically straightens out. Particularly striking was an example with alternating right and left-hand bias of 40° at approximately 2-in. intervals.[22] [See Fig. 2 (*a*).] It is difficult to see how such zig-zag forms could be straightened by steaming. I am not concerned here with the technical aspect, interesting though it is, but with the chemical reasons behind it.

The disulphide linking is the point of attack by sodium sulphide, and there seems no doubt that it is this cross linkage which is mainly concerned in the spirality removal. The enormous swelling, and considerable automatic increase in length occurring when the fibre is immersed in sodium sulphide, are consequences of the reduction of this grouping to free cysteine side chains. The long chains can now increase their distance apart, and also uncoil. With removal of the sulphide the turgescence subsides, and each cysteine side chain takes its nearest available mate to re-form, by normal air oxidation in less alkaline solution, new cystine bridges, to maintain the fibre in a new unstrained condition.

The conditions for practical success are those which will give as complete reduction as possible of the cystine links, without further decomposition, followed by as complete as possible re-conversion to the new cystine bridges. Incidentally, the greater the number, i.e. the higher the sulphur content, the more rigid should be the new set.

This opens up interesting speculations as to finishing effects from permanent *twist* as distinct from permanent elongation, and suggestions as to practical means, other than by sodium sulphide, of efficiently producing them, but I do not wish to enter upon that here.

It will, however, be realised that from the earlier work on sulphur content to our present knowledge of the part it plays in the structure and processing properties of wool, is a remarkable advance, and further elucidation of its functions can scarcely fail to bring new technical effects into the wool industry.

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London Section

Meeting at the Institute Rooms, 104 *Newgate Street, London, on* 22*nd February* 1933; *Mr. R. S. Meredith in the chair.*

THE PREPARING AND SPINNING OF YARN FOR AND THE MANUFACTURE OF ROPES

A lecture on the above-named subject was delivered by Mr. Donald Frost, of British Ropes Ltd. The lecturer was introduced by the Chairman as responsible for a very interesting visit by members of the Section to Messrs. British Rope Factory at Charlton.

Mr. Frost first named the fibres from which ropes and cordage had been made in the past. Of these, he said, hemp and flax were unquestionably the best; and for all cordage, exceeding a line in size, hemp had been generally preferred. During the past 30 years manila, New Zealand hemp, and sisal had been used in increasing quantities. Russian hemp had been replaced largely by Italian and Indian hemp, and the old-time tarred Russian hemp shrouds had been almost entirely superseded by steel-wire rope. He also referred briefly to the claims advanced in favour of sisal and to the experiments carried out and still being made in the use of this fibre.

Quoting from an old description of the art of rope-making which he stated was still accurate, the lecturer said the aim of the rope-maker was to unite the strength of a great number of fibres. These had to be combined or entangled in such a manner so as to get yarn strength without separation of the individual fibres by pulling out. The component fibres in a yarn can be compressed upon each other to any desired degree and the friction upon each fibre may be such that it breaks rather than slips. Equable distribution of the fibres throughout the skein will result in even distribution of strength. It was possible to twist a skein of fibres so hard that additional twist would break the whole yarn—such a yarn could carry no weight. Fundamentally, therefore, all twisting beyond that requisite to retain the individual fibres without slippage diminished the strength of the cord. Merely twisting a bundle of fibres together would not suffice. It was necessary to continue the twist so that tendency to untwist in one place or part acted against the same tendency elsewhere and balanced it.

After pointing out that in time past rope yarn was hand spun, the lecturer continued his description of modern methods, confining himself mainly to the production of yarn for ropes for marine and general purposes.

Most of this yarn, said the lecturer, is spun as 24 or 25 thread yarn, which meant that 24 such yarns were required for a strand of a three-stranded rope of 3 in. circumference. This size and type of rope was the basis of rope-making. A 40-thread yarn was therefore smaller, as 40 such yarns were required to make the strand of a similar rope.

Mr. Frost next proceeded to survey the manufacture of ropes in chronological order and said that the first department of a modern spinning mill was the fibre store which might contain some thousands of bales of the various fibres employed. Of each fibre there were to be found different grades and the lecturer dealt with these briefly. From the fibre store he passed to the preparing room where the bales are opened, the heads taken out and stacked into a large pile, often a mixture of various grades. Most spinners preferred to mix their fibres either to control colour, or strength or texture.

The next question dealt with by Mr. Frost was that of batch or lubricant. This usually consisted of a light mineral oil and lanoline with a small proportion of water, the whole emulsified into a cream. This softens the fibres in preparing and spinning and lubricates the finished rope. In his opinion batch was essential, and the percentage to be employed varied according to the purpose for which the rope was required and its manner of manufacture. It also served the purpose of waterproofing the rope to a considerable extent. The spreader or No. 1 goods machine was next in order, said Mr. Frost, and it consisted of two continuous chains or sheets bearing bars into which spikes, or hackle pins are driven—the operating width of these sections of spikes is from 20–24 in. The chains were driven and controlled by shafts and sprockets at each end—the front chain speed being about ten times that of the rear chain. At the rear was a feed board and feed rollers and at the other end drawing off and delivery rollers. In this country it was usual to have a short feed or spread board operated by one spreader with one or two assistants. This machine makes the separate heads of fibre into one continuous sliver and begins the fining down of the fibre and gets rid of some tow and dust. The aim of the spreader is regularity of overlap of each head and equality of thickness of the sliver. If time and space permitted, batch could be applied before the fibre came to this machine, but more usually it was applied throughout the first three processes in the mill—whichever method was employed it must be employed evenly and uniformly.

Slivers from the No. 1 machine, continued the lecturer, are next put up at the back of a similar machine but which takes from 10 to 14 slivers from No. 1 machines and marries them into one. It has a chain speed difference of 10 or 12 to 1, and thus its single sliver is similar in size to each of the 10 or 12 slivers introduced at the back. Four or five similar machines follow this one, each finer than its predecessor; that is the pins or hackles are smaller and closer together.

The lecturer then referred to the necessity of securing the correct weight of sliver and described the methods employed to ensure this. He also referred to the arrangement of machines in a mill and described a new delivery trunk which avoided a good deal of human attention.

Mr. Frost continued his description of the spinning processes by describing the spiral drawing machines. He pointed out that the difference between these machines and the chain drawing machines was that in the former the sliver was drawn through the pins by the drawing and pressing rollers, whereas in the other machines the hackle pins combed out the fibres. The spiral drawing machines had a distance between retaining and drawing rollers of about 7 ft. and they usually had a draft of from 10 to 15, and from 6 to 12 slivers were fed to each machine. A set of these was generally employed, three or four being usual, and in each succeeding machine the pins are finer and closer set. An important point was to have sliver cans as large as possible and to keep them clean. The finished sliver is then taken to the spinning frames.

Modern spinning frames, said Mr. Frost, were designed by Mr. J. Good. The machine has a horizontal chain bearing hackle pins, much smaller than those on the preceding machines, and a horizontal flyer large enough to carry a bobbin 8 in. in diameter and 10 in. long. The sliver is delivered to the flyer by a pair of haul-off pulleys, and the speed at which these are driven governs the turns per foot put into the yarn. The speed of the flyer remains constant, and therefore the sliver delivery is altered to alter the turns put into the sliver. These machines run at about 1,600 revolutions per minute and are capable of turning out approximately 1¼ cwts. of 24-thread per spindle per day—with smaller counts the production is reduced. An alternative, now being increasingly employed, said Mr. Frost, is a modern edition of the old gill spinning machine which had been much improved recently. It has a high speed flyer, an excellent friction device for the bobbins, and an automatic doffing arrangement.

Referring to the yarns themselves, the lecturer pointed out that certain fibres, such as Italian hemp, would stand more twist in the yarn than others. The yarn usually employed for marine ropes was 24-thread of 108 yards to the pound; 30 and 40-thread was occasionally used, and in the fishing trade up to 80-thread was employed to prepare small cordage required to be dead level and to withstand chafing. Rope to be dyed or tarred was at this stage wound into hauls prior to the process. It was to be noted that the preparation of the sliver and the spinning of the yarn was of great importance, having regard to the need to make good ropes.

Mr. Frost then gave a brief explanation of the first principle of rope making. He pointed out that if two yarns were twisted or doubled together at one end in a direction contrary to the twist in the yarns and their opposite ends were allowed to run freely, then the doubling twist caused the yarn twist to run out at the free ends. If, however, the free ends were each twisted in the same direction as the doubling twist the original yarn twist was put back into the single yarns Up to recent years, he said, rope was made in a rope-walk or rope-ground, but to-day it was also made on what were called House machines. The rope-walk was from 170–200 fathoms in length and was fitted with as many sets of machines as the weekly output demanded. One set of machines consisted of a traveller and the fore-end or sitting machine. Each machine carries a number of revolving hooks arranged round a centre driving pinion, or sometimes two pinions to allow two different speeds.

The traveller also bears a centre hook on the main shaft with a direct drive and a much slower speed. The yarns required are carried on bobbins on banks of spindles so arranged as to be drawn off under equal tension. Attached to the fore-end machine is a frame for taking register plates and a steam-heated tube chamber; both plates and tubes being themselves interchangeable. The register plates are drilled with a number of concentric holes through which yarns are rove varying in number according to the size of strand being formed. The strands are formed by passing a number of yarns through each tube and attaching them to the hooks on the traveller. The lecturer then described the method of driving the machines employed and continued his account of the preparation of the rope. The traveller bearing the strands is set in motion, moving away from the stationary fore-end machine. It pulls the yarns through the register plates and the tubes at a given speed and puts turns into the strands in a controlled manner. The usual angle of formation for a three-strand plain or hawser-laid rope is 27° and that the strands were usually formed in a direction contrary to that in which the yarns were spun. When the traveller has run its pre-determined distance, say 150 fathoms, it is stopped and the fore-end attendant cuts off the strands (three in the case of a three-strand rope) and attaches them to three hooks on the fore-end machine. It is usual then to rotate the hooks on each machine in opposite directions, putting what is termed "hard" into the strands. This practice the lecturer said he did not much favour. After making all three strands the same length, an important point, they are detached from the traveller hooks and attached to the single hooks thereon. The turn clutch is reversed so that the hook on the traveller and those on the fore-end machine revolve in the same direction. The strands are laid under the control of a third machine known as the top-cart. This is a trolley on which the top—a cone of hard wood grooved to receive the strands—is carried. The top cart is propelled by gearing connecting it to the endless band drive of the other machines in the set. Here the principle previously described comes into operation, said Mr. Frost, and the traveller hook twists the strands together but takes the fore turn out of the strands. These are attached to the fore-end machine hooks which, revolving in the same direction, puts back this turn and keeps the original formation in the strands. As the top cart moves towards the traveller, he said, the traveller moves slightly inwards since the rope becomes shorter during laying. The correct lay for a rope of the type described is at an angle of 37°. It is now reeled, bound and packed for despatch. A hard rope gave a lower breaking strain than a soft laid rope but would probably wear better. Other types of ropes were mentioned by the lecturer, such as four-strand or shroud-laid rope. This was approximately 5% heavier and 10% weaker than the three-strand rope, but it had a greater wearing surface and would withstand more chafing. There was also the cable-laid type of rope which could be three, four or even five-strand and was made by laying together in the opposite direction rope which had been previously laid. The three-strand cable-laid rope was 10% lighter than hawser laid rope and had a strength approximately 33⅓% less. Cable-laid ropes were more resilient than the hawser-laid type and were used frequently for towing purposes where elasticity was an advantage.

A hearty vote of thanks was accorded the lecturer for a very much appreciated address.

Midlands Section

A joint meeting of members of the Section with the Midlands Section of the Society of Dyers and Colourists was held at the Brailsford Cafe, Green Lane, Derby, on Wednesday, 14th February 1934. Mr. W. Pritchard, of the L.M.S. Railway Textile Research Department, gave a lecture on "Textiles Purchased by British Railways and their Application", which was much appreciated by a good attendance of members of both organisations. Mr. J. Chamberlain, of Leicester, presided, and a vote of thanks to the Lecturer was accorded on the proposal of Mr. Walker, of Nottingham, seconded by Mr. Edwards, of Loughborough.

NOTES AND NOTICES

President of the Institute

At the Annual General Meeting of the Institute, which is to take place at Manchester on the afternoon of the 16th May, the agenda will include the election of President. The Council decided, at a recent meeting, that Sir Thomas Robinson, J.P., be invited to accept nomination for election at the Annual Meeting. Sir Thomas, who is Vice-Chairman of the Bradford Dyers' Association and is first Mayor of Stretford under the new Charter, has kindly accepted the nomination for election in succession to Sir William Clare Lees. Notices in respect of the Annual Meeting will be issued to members in due course. The Annual Report of Council, together with Balance Sheet and Accounts for 1933, as printed in this issue, will be presented for adoption and the usual business will be transacted. The Council will make nomination as to the office of President and it has also been decided to nominate Messrs. W. Frost and E. Midgley for re-election, and T. Morley for election as Vice-Presidents.

Institute's Annual Conference

The response to the preliminary announcement issued to members provides definite indication that the Conference, which is to take place at Grange-over-Sands during next Whit-week, will be associated with a really excellent attendance. Final notice, with outline of Programme and Attendance Form will be issued shortly after Easter. Meanwhile, members contemplating attendance with accommodation at the Headquarter's hotel are advised to proceed without delay in the matter of booking of rooms. The next notice will provide particulars as to alternative accommodation. The final programme, copy of which will be sent to all who have notified attendance, will be presented in the form adopted in connection with the previous Conference. One important revision, however, has been decided upon by the Committee in charge of the Conference arrangements. The meetings for papers and discussions will be conducted under a definite time-table. There will be a reception on the Wednesday evening and the Conference proceedings will begin on the Thursday morning. On the afternoon of Thursday, there will be an excursion and in the evening the Institute Dinner will take place. The Conference will be resumed on the Friday morning (the concluding day), and at 2.30 p.m. the Mather Lecture is to be delivered. Mr. A. P. Young, O.B.E., M.I.E.E., M.I.A.E., of Rugby, whose recently-published book, entitled "Forward from Chaos: The Planning of Industry", has gained great attention, has kindly accepted the invitation of the Council to contribute this year's Mather Lecture. "Forward from Chaos" has been described as "a practical book written by a man of affairs who is also a man of vision. It breathes reason, goodwill, and optimism—but it also breathes the common sense of our industrial future."

Institute Membership

At the February meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—W. Hope, 5 Kingsway, Westwood Park, Pendlebury (Inside Manager, A. & G. Murray Ltd., Manchester); R. Jones, 28 Dove Street, Saltaire, Shipley (Testing Overlooker); G. M. Nabar, College of Technology, Manchester (Student); F. Shuttleworth, "Chez Soi", Park Drive, Timperley, Cheshire (Sub-departmental Manager, Buyer, and Producer, United Africa Co. Ltd.); W. Walton, 44 Bolton Road, Sudden, Rochdale (Textile Machinery Salesman, Tweedales & Smalley (1920) Ltd.). *Junior*—J. B. Athey, 11 The Circuit, Withington, Manchester (in charge of Warp Knitting Plant); A. A. Bottomley, 43 Garthland Drive, Dennistoun, Glasgow (Asst. Manufacturer,

P. MacArthur & Co., Glasgow); R. H. Duckworth, 29 Hill View Gardens, Hendon, N.W.4 (Technical Assistant in Fabrics Department, British Launderers' Research Association); K. O. Parker, 193 Harwoods Road, Watford Herts. (Textile Testing Assistant, Harrods Ltd.); D. N. Shroff, 461 Chester Road, Old Trafford, Manchester (Student); J. Smith, 22 Broom Street, Swinton, Manchester (Cotton Spinner, Monton Mill); S. N. Uddin, College of Technology, Manchester (Student); Constance A. Wyatt, Crossway, West Buckland, Taunton (Laboratory Assistant, Fox Bros. & Co. Ltd.).

COUNCIL'S ANNUAL REPORT, BALANCE SHEET, AND ACCOUNTS FOR 1933

To be presented at the ANNUAL GENERAL MEETING
Wednesday 16th May 1934

COUNCIL'S ANNUAL REPORT

The records of the past year emphasise the outstanding importance of three features of the Institute's activities—the professional qualification of members, the publication of scientific and technical controbutions to textile literature, and the promotion of the Annual Conference and other meetings for the presentation and discussion of papers. The Council expresses its warm appreciation of the enthusiastic service given by members of the Committees concerned with the direction of these affairs.

The matter of premises for the Headquarters of the Institute has been under careful review for some time past and a special sub-committee carefully considered the whole position from many aspects. The fact that the period of the lease was drawing to a close prompted consideration of many alternatives. Finally, however, the conclusion was reached that solid advantages would accrue from a renewal of the lease. Suggestions for the extension of storage accommodation were approved and negotiations were successfully carried out for retention of the existing premises, which have been vastly improved as to equipment and furnishing in recent years. The terms impose some advance in rent but the position is considered comparatively favourable.

Although the accounts for the past year reveal a small deficit, the Council regards the financial position of the Institute with satisfaction. For many years past, the Finance Committee has pursued a policy of conservation of the financial resources, the effect of which is now proving most beneficial, as may be seen by reference to the schedule of investments. Reduced annual interest on the sums invested forms a serious consideration but, fortunately, it has been possible to effect several economies without sacrifice of efficiency. By far the largest outlay each year is that incurred for printing the *Journal*, but the present contract is on more favourable terms than formerly.

The membership strength of the Institute remains undiminished in consequence of the steady influx of fresh applications at each monthly election. Additions recorded in the current year give promise of satisfactory expansion in the near future.

Annual Conference

The Conference held at Harrogate during Whit-week of last year continued the plan under which all papers contributed dealt with some aspect of one general subject—on this occasion that of Problems of Finishing. The comprehensive treatment of a general subject has been found to be of considerable advantage from the point of view of the published records and there is still a demand for re-prints of papers read at previous conferences.

At the Harrogate Conference the Mather Lecture was of special interest owing to the fact that it was contributed by Dr. T. Oliver, of Galashiels, who is a Life Member of the Institute. The Institute Medal was awarded to Mr. F. W. Barwick (Manchester) for services to the Institute, particularly in relation to the work of the Selection Committee over which the recipient has presided for several years.

The next Conference is to be held at Grange-over-Sands in the latter part of Whit-week. Arrangements are already in progress and an excellent response to invitations to contribute papers on the subject of "Conversion of Yarns into Fabrics" (embracing Weaving, Knitting, and Lace-making) has been secured.

Journal of the Textile Institute

The Publications Committee realised quite early in the year that the revenue from all sources might be definitely reduced. With no diminution in matter for publication, every endeavour was made to reduce expenditure commensurately. The situation was met and a fair measure of success secured, the amount to be transferred from the Foundation Fund income being less for 1933 than for 1932. It is also gratifying that the revenue from *Journal* subscriptions has been maintained.

In the matter of contents, a continued world-wide interest may be recorded. Papers for the Transactions have been published during the year from the British Cotton Industry Research Association (8 contributions); Wool Industries Research Association (5); Linen Industry Research Association (1); British Silk Research Association (1); Indian Central Cotton Committee (1); College of Technology, Manchester (2); University of Leeds (3); Institute of Animal Genetics, Edinburgh (1); University College, Nottingham (3); Massey Agricultural College, New Zealand (2); Institute of Technology, Massachusetts U.S.A. (1); Bell Telephone Laboratories, U.S A. (3); Federal Institute of Technology, Zurich, Switzerland (1); and from private sources (5). The *Abstracts* Section has received the continued support of the Research Associations and other abstracting organisations and individuals. This has made it possible to render the same services as in previous years and no reduction in this work is apprehended. The *Proceedings* Section was conducted on the same lines as in the previous year and contained all the papers contributed to the Annual Conference at Harrogate. These dealt with various aspects of the same general subject—Finishing.

The *Library*, which is conducted by the *Journal* staff, has definitely grown in size and in usefulness and a catalogue of all additions to September 1933 is now available. Increased accommodation is being provided to meet the steady flow of additions to the Library.

It has been decided also to publish some of the inquiries received by the Information Bureau. This can only be done when the inquiry is of a general character and where replies are considered of value to all members. The consent of the inquirer and of those who furnish replies will precede publication and already instances have arisen in which this course has proved valuable.

Institute Diplomas

The Institute's Examination established in connection with applications for the Associateship now comprises two parts, Part I (Auxiliary Subjects) having been created in order that certain candidates may, by passing, meet the requirements of the Regulations in regard to general education; Part II covers General Textile Technology as before. Applications for Institute Diplomas during 1933 totalled 48 (11 Fellowship and 37 Associateship) as compared with 50 in the previous year (6 Fellowship and 44 Associateship). The total number of applications, since the inauguration of the scheme of qualification of members in 1925, is 725 (270 Fellowship and 455 Associateship). The 1933 Examination of applicants for the Associateship was held simultaneously at Manchester, Glasgow, Leicester, Belfast, Bombay, and Calcutta, when there were 2 candidates (both passed) for Part I, and 32 for Part II (24 passed).

The Selection Committee has had under prolonged consideration a scheme for the establishment of National Certificates in Textiles. A joint committee of representatives of the Board of Education and the Instutite was appointed and at a meeting in the early part of the present year a draft scheme was approved for presentation to the Selection Committee with a recommendation that it be submitted to the Council of the Institute and the Board of Education for acceptance.

Institute Scholarships

The first Institute Scholarship, awarded under the terms of the scheme established by the aid of a special grant on the part of the Cotton Reconstruction Board and the Cotton Trade War Memorial Fund, was completed last midsummer. The holder (Mr. Alan Ratcliffe, A.T.I.) after a special course of training covering two years at Manchester College of Technology, proceeded to the Continent with a view to extending his practical experience, and was engaged in voluntary service, first in the Chemnitz district of Germany and later in the mills of Mr. Windfeld-Hansen at Veile, Denmark. Mr. Ratcliffe, who achieved distinction at the College and secured reports of marked appreciation of his voluntary services on the Continent, was able to obtain an early engagement when, in October last, he entered upon an important post on the side of management at the chief works of Messrs. Morton Sundour Ltd., at Carlisle. The second Institute Scholarship holder (Mr. Wm. Graham, A.T.I.) has entered upon his third year of training. After two years at College, he proceeded to the works of Messrs. Diederichs at Ste. Colombe, France, and later, to the mills of Messrs. G. Garnett & Sons Ltd., Apperley Bridge, near Bradford. To all the firms concerned with the granting of facilities for voluntary service, the Council offers their warmest thanks. The annual income from the funds invested for scholarship purposes is diminished owing to reduction of the rate of interest. An appeal to the original donors for a supplementary grant has resulted in a further contribution of £500, which amount has been invested and gratefully acknowledged.

Competitions: Design and Structure of Fabrics

The Institute's competitions in relation to design and structure of fabrics have been well maintained. The scope has in fact been extended, and the scheme now embraces woven fabrics, knitted fabrics, yarns, and designs for printed fabrics. The introduction of the last-named feature proved somewhat disappointing but the restriction as to age of competitors has now been relaxed and the experience of the conditions for the current year should be interesting. The income of the scheme is considerably diminished as a result of decreased yield from investments. Fortunately, however, individual donations amounting to £26 1s. (£10 Anonymous, £10 Mr. Frank Wright, £5 Messrs R Greg & Co. Ltd., and £1 1s. Mr. H. G. Greg) relieved the situation considerably. The Council expresses warm appreciation of these gifts and hopes that the value of the competitions may find extended recognition in the form of similar donations.

There were 106 competitors for the year as against 82 in 1932.

Council and Committee Meetings

The following is the record of meetings during 1933 --Council, 11; Finance and General Purposes, 11; Selection, 10; Library, 3; Publications, 11; Competitions, 3, Scholarships, 3; Dictionary and Fabrics Collection, 1; Lancashire Section, 1; London Section, 3; Midlands Section, 2; Yorkshire Section, 1; Irish Section, 0; Scottish Section, 3; total 61, as against 57 in the previous year. In addition, eight sub-committees met for the consideration of special matters.

Section Meetings and Lectures

Five meetings of the Lancashire Section and two joint meetings; six of the Yorkshire Section; seven of the London Section (and one visit); one of the Irish Section; three of the Midland Section (and three visits); and two of the Scottish Section (and two visits), took place during 1933, at which papers were read and discussed.

Membership

The membership list at the end of 1933—to be carried forward to 1934--was made up as follows--Honorary Members, 8; Life Members, 39; Ordinary Members, 1258; Junior Members, 120; total 1425, as against 1428 at the end of 1932. Of the members at December 31st last, 169 had been admitted to the Fellowship and 289 to the Associateship.

The totals for the foundation year (1910) and other years named were 1910, 233; 1921, 904; 1926, 1,395; 1931, 1,443; 1932, 1,428.

The Council laments the loss by death during 1933 of many prominent members, including the following—G. R. A. Ainsworth (Manchester); A. Brusnikin (London); E. G. Harlow (Bradford); Sir Philip Magnus (London); F. Metcalfe (Oldham): W. L. Middleton (Halifax); H. Ostheide (Leeds); T. Fletcher Robinson (Manchester); A. G. Rolstone (London); T. Woodhouse (Blackpool).

Dr. The Textile Institute—Balance Sheet as on 31st December 1933 Cr.

LIABILITIES

1932 £ s. d.		£ s. d.	£ s. d.
131 14 6	Subscriptions paid in advance		133 10 0
	Life Membership Subscription Account—		
	Balance as on 31st December 1932	34 3 1	
34 3 1	*Less* 10% of £85 8s. 1d. transferred to Subscriptions Account	8 10 10	
			25 12 3
	Sundry Reserves, viz.—		
2500 0 0	Crompton Prize Fund	2500 0 0	
319 0 0	Life Membership Reserve Account	424 0 0	
97 10 0	Perpetual Membership Reserve Account ...	97 10 0	
10576 10 5	Foundation Fund	10576 10 5	
5000 0 0	Do. (Cotton Reconstruction Board Grant)...	5500 0 0	
861 9 6	Do. (Diplomas Account)	861 9 6	
250 0 0	Do. (London Section Reserve Account) ...	250 0 0	
			20209 9 11
26 8 1	Competition Scheme—Income and Expenditure Account Balance		
287 2 5	Scholarship Scheme Reserve Account		149 6 1
338 6 3	Sundry Creditors and Reserves as per list		240 16 11
741 0 8	Bank Overdraft—General Account		781 6 6
£21163 4 11			£21540 1 8

NOTE—There is a contingent liability for Income Tax in respect of final agreement of assessments for 1926-27 to 1933-34 inclusive.

ASSETS

1932 £ s. d.		£ s. d.	£ s. d.
164 4 5	Cash at Bank—Foundation Fund		514 4 5
25 12 6	Cash in Hand		28 0 7
	Sundry Debtors—		
	Journal Account—		
306 1 6	Outstanding Adverts.	324 7 10	
35 6 8	Outstanding Reprints	57 6 6	
			381 14 4
	Furniture, Fittings, and Library Account—		
	Balance as on 31st December 1932	472 1 9	
	Additions (*less* Sales) during year	100 10 0	
		572 11 9	
472 1 9	*Less* Depreciation	100 7 4	
			472 4 5
	London Furniture Account—		
	Balance as on 31st December 1932	28 0 10	
28 0 10	*Less* Depreciation	4 0 1	
			24 0 9
9 10 0	Gas and Electricity Deposits		9 10 0
90 16 11	Stock of *Chronological Records*, etc. (estimated value)		84 7 8
	Investment Account (see Schedule)—		
16515 14 0	Foundation Fund	16515 14 0	
2500 0 0	Crompton Prize Fund	2500 0 0	
105 0 0	Life Membership Account	105 0 0	
97 10 0	Perpetual Membership Account	97 10 0	
			19218 4 0
43 11 1	Office and Rooms Alteration Account—Balance ...		
	Revenue Account—		
	Balance as on 31st December 1932	769 15 3	
769 15 3	*Add* Excess Expenditure over Income for Year	38 0 3	
			807 15 6
£21163 4 11			£21540 1 8

AUDITORS' REPORT TO MEMBERS

We report to the members that we have examined the above Balance Sheet, together with the books and vouchers of the Institute, and that we have obtained all the information and explanations we have required. We further report that in our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of our information and the explanations given to us, and as shown by the books of the Institute.

W. W. L. LISHMAN *Hon. Treasurer*
F. WRIGHT *Chairman of Council*
W. FROST *Chairman, Finance Committee*

28th February 1934
37 York Street, Manchester

(*Signed*) ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors

Dr. The Textile Institute—Revenue Account for the Year ended 31st December 1933 Cr.

1932 £ s. d.	EXPENDITURE	£ s. d.	£ s. d.
	To Rent and Rates—Manchester	273 16 4	
177 11 3	*Less* to *Journal* Account	91 5 5	
			182 10 11
	„ Salaries	1318 9 0	
650 0 0	*Less* to *Journal* Account	668 9 0	
			650 0 0
	„ Wages	419 8 4	
280 17 6	*Less* to *Journal* Account	123 10 0	
			295 18 4
	„ Heating, Lighting, and Cleaning	77 11 6	
64 12 3	*Less* to *Journal* Account	25 17 2	
			51 14 4
71 8 9	„ Offices, Canteen, and General Expenses		71 8 4
48 2 8	„ Meetings and Travelling Expenses		46 14 4
97 6 9	„ Postages, Telegrams, and Telephones		101 5 5
128 1 8	„ General Printing and Stationery		125 19 6
6 11 11	„ Insurances		6 18 11
21 18 0	„ Audit Fee		32 1 0
3 3 0	„ Subscriptions to Institutions		3 3 0
68 9 4	„ Library Account		26 11 3
57 8 1	„ Diplomas Account Expenses		35 12 8
2 14 0	„ Medal Account		1 6 6
12 2 6	„ Painting and Decorating		2 13 0
37 12 0	„ Savings Association Contributions		43 4 0
69 12 9	„ Annual Conference Expenses		97 9 3
2 13 0	„ Information Bureau Account		– – –
14 8 1	„ Bank Charges *less* Interest		13 11 4
	„ Section Expenses—		
140 16 1	London (including Office and Rooms)	144 0 11	
15 3 9	Lancashire	26 0 0	
33 10 5	Yorkshire	41 4 5	
3 13 2	Scotland	9 1 1	
5 9 6	Ireland	5 0 2	
2 4 8	Midlands	4 10 11	
			2 9 17 6
43 11 2	„ Office Alterations—		
	Amount written off		43 11 1
76 16 1	„ Depreciation on Furniture		104 7 5
2135 18 4			2165 18 1
143 16 11	„ Excess Income over Expenditure for Year		– – –
£2279 15 3			£2165 18 1

1932 £ s. d.	INCOME	£ s. d.	£ s. d.
	By Membership Subscriptions—		
	1137 Members at £2 2s.	2387 14 0	
	1 Member at £1 1s.	1 1 0	
	18 Members at £1 1s. (half year)	18 18 0	
	5 Members at 10s. 6d. (quarter year) ...	2 12 6	
	99 Junior Members at £1 1s.	103 19 0	
	9 Junior Members at 10s. 6d. (half year) ...	4 14 6	
	Life Members—10% of Balance	8 10 10	
	Subscriptions in Advance as per Balance Sheet 31st December 1932	131 14 6	
	Subscriptions in Arrear paid during 1933 ...	97 5 2	
	Interest from Diplomas, Life Membership, and Perpetual Membership Investments ...	36 12 0	
	Special Subscription—The Weavers' Company	21 0 0	
	Diploma Fees	132 6 0	
		2946 7 6	
1993 11 8	*Less* Amount transferred to *Journal* Account ...	1031 4 8	
			1915 2 10
20 0 0	„ Crompton Fund Administration Expenses		6 8 1
266 3 7	„ Foundation Fund Income from Investments Account		206 6 11
2279 15 3			2127 17 10
– – –	„ Excess Expenditure over Income for Year		38 0 3
£2279 15 3			£2165 18 1

SUBSCRIPTIONS—

TOTAL ARREARS at 31st December 1933 ...	£233 2 0
ARREARS written off	5 5 0
Total Arrears Current	£227 17 0

Audited and found correct
28th February 1934
37 York Street, Manchester

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors

Dr. The Textile Institute—Journal Account for the Year ended 31st December 1933 Cr.

1932 £ s. d.	EXPENDITURE	£ s. d.
2395 16 4	To Printing, Reprints, and Postages (Distribution)	2161 17 11
42 19 3	„ Literary Contributions and Abstracts	43 13 1
663 16 0	„ Salaries	668 9 0
116 10 10	„ Wages	123 10 0
73 14 10	„ Postages, Telegrams, and Telephone	68 5 6
9 16 9	„ Stationery, Binding, and *Journals* purchased	32 15 6
174 18 11	„ Advertisement Commission...	143 14 11
32 5 3	„ Travelling Expenses	12 10 7
88 15 7	„ Rent and Rates (Proportion)	91 5 5
32 6 1	„ Heating, Lighting, and Cleaning (Proportion)	25 17 2
£3630 19 10		£3371 19 1

1932 £ s. d.	INCOME		£ s. d.
1940 18 7	By Advertisements and *Journal* Subscriptions		1818 7 3
160 0 0	„ *Journal* Subscriptions—		
	Linen Industry Research Association	£151 5 0	
	Wool Industry Research Association	84 0 0	
			235 5 0
10 10 0	„ Annual Donation—The Clothworkers' Company		10 10 0
215 13 0	„ Reprints		133 4 9
1073 9 9	„ Transfer from Membership Subscriptions		1031 4 8
230 8 6	„ Transfer from Foundation Fund Income from Investments Account		143 7 5
£3630 19 10			£3371 19 1

The Textile Institute—Crompton Prize Fund Scheme : Competitions

Dr. Income and Expenditure Account for Year ended 31st December 1933 Cr.

1932 £ s. d.	EXPENDITURE	£ s. d.
22 2 1	To Printing and Stationery	24 4 4
49 19 6	„ Purchase of Specimens	32 6 1
16 19 9	„ Mounting of Specimens	19 5 0
158 19 9	„ Prize Awards and Expenses	186 13 3
11 5 8	„ Postages and Carriage	9 18 4
20 0 0	„ Administration Expenses	6 8 1
279 6 9		278 15 1
26 8 1	„ Balance carried forward	- - -
£305 14 10		£278 15 1

1932 £ s. d.	INCOME		£ s. d.
69 9 10	By Balance brought forward		26 8 1
139 1 0	, Albums—Subscriptions	£143 5 0	
- - -	, Sundry Donations	26 1 0	
			169 6 0
11 4 0	„ Competition Entrance Fees		14 6 0
50 0 0	„ Dividend on £1000 3½% War Stock	35 0 0	
24 15 0	„ Dividend on £1125 4% L.M.S. Railway Stock ...	25 6 3	
			60 6 3
11 5 0	Income Tax Repayment		8 8 9
£305 14 10			£278 15 1

Audited and found correct
28th February 1934
37 York Street, Manchester

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors

Dr. The Textile Institute—Foundation Fund Income from Investments Account for the Year ended 31st December 1933 Cr.

EXPENDITURE

1933		£	s.	d.	£	s.	d.
June 2	To Mather Lecture	...		...	25	0	0
Dec. 31	„ Interest on £844 9s. 2d. 3½% War Loan (Diplomas) transferred	29	11	0			
„ 31	„ Interest on £102 5s. 3½% War Loan (Life Members) transferred	3	11	9			
„ 31	„ Interest on £99 1s. 6d. 3½% War Loan (Perpetual Members) transferred	3	9	3			
„ 31	Interest on £240 3½% War Loan (London Section) transferred	8	8	0			
„ 31	„ Interest on £4870 3½% War Loan (Scholarships) transferred	170	9	0			
„ 31	„ Interest on £1000 3½% War Loan (Crompton) transferred	35	0	0			
					250	9	0
„ 31	„ *Journal* Account	...		...	143	7	5
„ 31	„ Revenue Account	...		...	206	6	11
					£625	3	4

INCOME

1933		£	s.	d.
Feb. 1	By Dividend—£1242 10s. 4% Consolidated Stock, *less* tax	18	12	9
May 1	„ „ £1000 4% Funding Loan 1960–90, *less* tax	15	0	0
June 1	„ „ £15939 18s. 10d. 3½% War Loan	278	18	11
Aug. 1	„ „ £1242 10s. 4% Consolidated Stock, *less* tax	18	12	9
Nov. 1	„ „ £1000 4% Funding Loan 1960–90, *less* tax	15	0	0
Dec. 1	„ „ £15939 18s 10d. 3½% War Loan	278	18	11
		£625	3	4

Dr. The Textile Institute—Scholarships Scheme Income and Expenditure Account for the Year ended 31st December 1933 Cr.

EXPENDITURE

1933		£	s.	d.	£	s.	d
Dec. 31	To Scholarship Holders' Maintenance Allowances—						
	Alan Ratcliffe	122	10	0			
	William Graham	184	14	1			
					307	4	1
„ 31	„ Postages	.		...	2	2	3
					309	6	4
„ 31	„ Balance carried forward	...		..	149	6	1
					£458	12	5

INCOME

		£	s.	d.
1932 Dec. 31	By Balance brought forward...	287	2	5
1933 Sep. 4	„ Refund of College Breakage Deposit	1	1	0
Dec. 31	„ Interest on £4870 3½% War Loan	170	9	0
		£458	12	5

Audited and found correct

28th February 1934 ARTHUR E. PIGGOTT, SON & SOUTHWORTH

37 York Street, Manchester *Incorporated Accountants Auditors*

INSTITUTE FOUNDATION AND OTHER FUNDS

SCHEDULE OF INVESTMENTS

(at Cost or Value at original date of gift) **as on 31st December 1933**

				£	s.	d.	£	s.	d
Foundation Fund—									
£3737	14	9	3½% War Loan	3503	7	0			
£4789	9	5	Do.	4789	9	5			
£ 48	16	3	Do.	49	14	1			
£ 105	5	3	Do.	106	14	0			
£ 102	17	6	Do.	5355	0	0			
£4870	0	0	Do. (Scholarship Scheme)						
£ 240	0	0	Do. (London Section)						
£ 650	0	0	Do. (Diplomas)	661	9	6			
£ 194	9	2	Do. (Diplomas)	200	0	0			
£1000	0	0	4% Funding Loan 1960–90	800	0	0			
£1242	10	0	4% Consolidated Stock	1050	0	0			
							16515	14	0
Crompton Prize Fund—									
£1000	0	0	3½% War Loan	1000	0	0			
£1125	0	0	4% L.M.S. Railway Preference Stock	1500	0	0			
							2500	0	0
Life Membership Account—									
£ 52	5	0	3½% War Loan	53	14	6			
£ 50	0	0	Do.	51	5	6			
							105	0	0
Perpetual Membership Account—									
£ 99	1	6	3½% War Loan				97	10	0
Nominal Value—									
£19307	8	10							
							£19218	4	0

The Market Value of the above securities on
31st December 1933 was approximately £19376 1 9

(Securities at National Provincial Bank Ltd.)

Audited and found correct
28th February 1934
37 York Street, Manchester

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors

REVIEW

Modern Textile Microscopy. By J. M. Preston, with a Foreword by F. Scholefield. Published by Emmott & Co. Ltd., 1933. (Pp. xi+315, with 134 figures. Price 15s.)

It is a firm and natural conviction of every author of a scientific text-book that there is a perfectly definite, or even desperate, need for such a book as he proposes to write. Mr. Preston, on his own confession, is no exception to this rule, so that at the outset, since we are very much inclined to share his conviction, he is to be heartily congratulated, both on his insight and on his courage in undertaking a task which might well have daunted a lesser enthusiast. That it has involved some heavy reading is obvious from the number of references quoted, 351 in all, and if only on this account and that of the wealth of scientific fact and theory brought under review between one pair of covers, "Modern Textile Microscopy" is assured of a ready reception among the steadily growing band of textile research workers that this age, however reluctantly, is bound to foster. We are living in some stupid times, without doubt, but at least they are scientific times, and it would be an amazing thing if sooner or later we did not learn to think correctly and make some decent use of the stores of knowledge that the human mind has so patiently garnered. Textile technology, of course, is Mr. Preston's particular interest, and here, too, by the same token, there is now little excuse for loose thinking or slipshod methods, for at last there is arising a true textile science, such as must one day grow to be nothing less comprehensive than the textile industries themselves—for above everything else, science is a way of thinking, not the prerogative of laboratories alone. In the new textile science—it is as yet only emerging—microscopy must play an important part; the microscope is one of the readiest supplements to the unaided senses, and there is so much it can tell us about the nature and uses of textile fibres.

The wholly admirable aim of "Modern Textile Microscopy" is to deal with the subject from A to Z, so to speak, or at least to include the majority of the letters and treat them in their proper order. Thus we are led steadily from the microscope and its manipulation to the preparation of sections and other material, their photography, micrometry, photometry, staining, swelling, etc. through ultra- and fluorescence microscopy and the appearance of surface structures, to a final chapter on the uses of polarised light. The range of topics is indeed wide, even as the author intended, and there are few points of interest that are not touched upon to some extent, though, to be sure, the examples given are mostly from among the cellulose fibres. One must suppose that this is due partly to the author's more intimate acquaintance with such fibres, and partly to the circumstance that the animal fibres, being more difficult, have as yet by no means received such thorough and logical optical investigation as they deserve, and in fact cry out for. Especially is this cellulosic bias evident in the chapter on polarised light—but perhaps it is not to be regretted, for the available optical information on wool and other animal hairs is undoubtedly "scrappy" and some of it is hardly worth recording. Fortunately, there seems to be now some prospect of remedying this defect at no very distant date.

There are a few scientific points on which we might be permitted a small grumble—such, for instance, is the discussion (p. 250) on the "merits" and "demerits" of the microscope method and the X-ray method. A discussion of this kind is just about as sensible as a comparison of the "merits" and "demerits" of wireless waves and ultra-violet light, of man and woman, of jazz and oratorio, and, in fact, of any pair of things, concepts, or what you will, which are peculiarly adapted each to certain special ends or functions. Among other statements also, which the author might consider worth redrafting stand out the following—"The amino-acids, tyrosin and hystidine, are liberated when wool is damaged" (p. 174); "Both the extinction angles (of *Valonia ventricosa*), as shown by polarised light and the equators of the spots on X-ray photographs of the membrane, coincide with the directions of the striations" (p. 193); "Some liquids will penetrate fibres easily; for instance, water, glycerol, and formamide" (p. 268); "The other method of measuring this quantity (double refraction) is to find the amount of retardation of the ordinary ray behind the extraordinary ray after passing through the fibre. For

$$\varrho = \frac{\delta\lambda}{d}(n_\gamma' - n_\alpha'),$$

where ϱ is the double refraction, δ is the retardation, d is the thickness of the fibre, and λ is the wave-length, all expressed in μ" (p. 270). All these statements are either incorrect or misleading.

There is, however, a blemish on this book which is not of a purely scientific character, but which is nevertheless perhaps more distressing to any one who feels at all sensitive on behalf of his own language, particularly in view of the scorn that is so often directed at scientific writers on the count of grammatical inaccuracy and general feebleness of literary style. For instance, not to mention a number of split infinitives, some of them rather painful, we meet such phrases as "different than" (pp. 14, 38, 82, 256, 269), "differently oriented than" (p. 254), "different to" (pp. 64, 255), "identical . . . . as" (p. 89), "this data . . . . is" (p. 197), "From this data" (p. 279), and a remarkable succession of isolated adverbial and other subsidiary clauses with regard to which the reader is left to take his choice between the preceding and subsequent principal clauses. No fewer than a dozen of these have been noted—may we hope that after all they are only misprints ?—of which the following may be given as an example (p. 20)—"Unfortunately, this movement prevents the accurate centring of the diaphragm when it is desired to have it in the central position. Though this lack of absolutely accurate centration is generally negligible for the class of work under consideration. Another diaphragm commonly used is an expanding patch stop." Again, the active and passive voices are treated with a similar impartiality, the author slipping dexterously from one to the other, as, for example, on p. 169, right in the middle of a set of directions.

These grammatical criticisms do not detract from the intrinsic scientific worth of the book, of course, and they are offered here, regretfully enough, in a spirit of helpfulness, just because with the author we also have the welfare of textile science at heart and feel strongly with him that there really is a need for such a book as he envisaged. Literary defects have a subtle psychological effect, and the scientific writer particularly—he has no throbbing, passionate tale to bolster up his shortcomings—must preserve a simplicity and purity of language if he is to retain the unqualified respect of his reader. Thus he owes it to himself not to let his purely scientific authority be diminished in any way by mere textual faults, for to the mind of many readers such faults, justly or unjustly, always reflect on the reliability of the subject matter. Even a small solecism like "X-ray spectroscopy", which Mr. Preston uses instead of "X-ray crystal analysis", can be distinctly worrying, for X-ray spectroscopy is not the study of the intimate structure of crystals, but the study of X-ray *spectra* as a branch of radiation and atomic theory.

For ease of preparation of the second edition the following misprints should be noted—p. 21, l. 1; p. 27, l. 7, ? ref. (104); Table III, 32 instead of 3·2; p. 91, Pierce instead of Peirce; bottom of p. 122, per cm. and per μ instead of cm. and μ; p. 125, 1·40 for the density of wool instead of 1.30; p. 141, Fig. 49 instead of 48; p. 202, l. 4, delete comma; p. 211, pendicular instead of perpendicular; p. 222, l. 11, delete $-=$; p. 250, election instead of electron; p. 253, l. 17, "index" omitted; p. 255, l. 25, bifringence instead of birefringence, and l. 37, X-rays instead of X-ray; p. 256, l. 13 from bottom, delete "a"; p. 268, l. 3 from bottom, comma instead of full stop; pp. 277, 278, and index, Chandron instead of Chaudron; p. 281, l. 5 from bottom, ? horizontally; p. 285, (kd) instead of (-kd); p. 267, Wiener's formula.

It would be a good thing, too, if there were more variety in the style of heading sections of the text; something should be done to show that many sections are really sub-sections to a previous section, even though the style of print in the heading is the same.

W.T.A.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXV APRIL 1934 No. 4

PROCEEDINGS

Lancashire Section

Meeting at the Institute, 16 St. Mary's Parsonage, Manchester, on Friday, 8th December 1933; Mr. T. E. Mitchell in the chair.

"COTTON: ITS TREATMENT UP TO THE FINISHED LAP"

A lecture on the above-named subject was given to members of the Section by Mr. Alan Ratcliffe (Associate) who had recently completed his tenure of the first Institute scholarship.

The lecturer first referred to the high-density bale and the use of the modern bale breaker. It was customary to use one machine of this type and to arrange the opened bales round it In this it was sought to mix cotton, differing in staple, grade, bloom, cleanliness, colour, and moisture content. If these differences were not too marked and if the mixing was thorough then no great trouble would ensue. But as count variations, the bugbear of the spinner, would arise if the mixing were faulty, there was necessity to ensure adequate mixing. It was the lecturer's experience that the mixing sheet was of such importance that the mill-manager made it out himself, but if ten bales were to go through it must be borne in mind that, at best, only cotton from four bales at a time was put into the hopper of the bale breaker. Proper mixing could not thus be secured. Nor was the stack-mixing method much improvement, said Mr. Ratcliffe, as it was not possible to secure its proper working. He suggested as a remedy the use of four bale-breakers and affirmed that the experiences of an American firm, which had tried the four-breakers system with success, had proved that no advantage would be gained by increasing the number of breakers from four to eight. The advent of the automatic distributor permitted of more satisfactory direct mixing, but he advocated stack mixing, using four bale-breakers, where floor space permitted.

Mr. Ratcliffe continued his survey by reference to the blowing-room and said that it was now generally admitted that the hopper feeder embodied the soundest principle of opening machinery. In it the cotton was combed apart and not violently knocked out. It was modern practice to employ two, or even three, of these machines in tandem with lessening distances between their evener lattices and upright lattices. An average speed was desirable and probably optimum, as too high a speed resulted in snatching, not combing, and also in incomplete stripping—which was to be avoided at all costs.

Continuing the lecturer said that at this point in most mills the cotton reached the first beater—either a 41½-in. Buckley cylinder or, as preferred by others, two 24-in. cylinders. The cotton was condensed by means of cages and fed to the 18-in beaters From this point onwards the choice lay between the bladed beater and the porcupine beater. The bladed beater (three blades being preferable to two) was, in most makes, almost surrounded by bars and had a great cleaning capacity but it "nepped" the cotton and broke it off in chunks from the roller nip and this resulted in a lumpy lap. The porcupine beater did not "nep" the cotton; its action on the cotton as presented by the rollers was a combing one and the cotton was presented to succeeding processes in a much better condition.

Unfortunately its cleaning power was considerably less than that of the bladed beater.

Mr. Ratcliffe suggested that exchange from bladed beater to porcupine opener had been tried and abandoned and that such a situation might be met by the introduction into the system of a Crighton opener. He repudiated the commonly-held idea that this machine was hard on the cotton and should be confined in its use to Indian cotton or low-class American. He described the machine and its method of working and stated that it was one of the gentlest of machines at the disposal of the spinner. Its cleaning capacity was 100% and it removed nothing but impurities. The bars should not be too closely set and the fan speed should correspond with the amount of cotton being fed.

Turning to the claims of the one-process blowing-room system, the lecturer advocated this as opposed to the opener and additional scutcher system. He did so as a result of experience in working both systems and on the following grounds—whereas the lap made by the lap-forming mechanism of the opener goes straight to the card in the one-process system, in the other system four laps are taken from the opener and fed up on the lattice of the scutcher. It is claimed that the advantages of doubling are thus secured and with the introduction of additional regulating mechanism a more regular lap was secured. But, he urged, the calender rollers of the last beater press the lap with a pressure of several hundred pounds and additional cleaning did not seem possible under such conditions. On the point of regularity he submitted that the regulating motion came into operation after an irregular place had passed the motion and so enhanced the very evil it was designed to remedy.

The last phase of his lecture, said Mr. Ratcliffe, was consideration of suitable standards and limits of accuracy in the lap—what weight was desirable per lap and per yard of lap ? For a 38-in. card the lap should weigh from 30 to 35 lb. A lap too heavy for the operatives was increasingly liable to damage; one too light entailed unnecessary piecings. In considering the variation per lap it was pointed out that the lap regulating motion worked according to the bulk or thickness of the lap whereas measurement was made of the weight per yard. The lecturer contended that these two aspects of the question could not be satisfactorily related and, as previously mentioned, the control through the pedals, levers, and cone drums is subject to such a time lag that the correction operates on the cotton following instead of upon the cotton which actuates the mechanism. Every endeavour should, therefore, be made to feed forward a constant amount of cotton. This can be secured by the utilisation of a Lord's feeder mechanism which knocks off excess cotton and returns it to the hopper.

The lecturer said that he would be satisfied with a standard 32-lb. lap with a 4-oz. tolerance each way and would appeal to the operatives concerned to use every endeavour to maintain this. He advised as complete mechanisation of the blowing-room as possible.

After some discussion on various points a hearty vote of thanks to the lecturer terminated the meeting.

Meeting at the Harris Institute Technical College, Preston, on Friday, 9th February 1934; Mr. F. Wright, F.T.I., in the chair.

RECENT WORK ON THE POWER LOOM*

Mr. W. A. Hanton, of the College of Technology, Manchester, was the lecturer on this occasion and in his address pointed out that during the past few years the power loom had been the subject of some considerable study, partly with a view to reducing or eliminating faults in cloth due to imperfect functioning of the loom, and partly to improve its general working, reduce its power consumption, and increase its production. In spite of all the hard things that have been said about it, the loom, in the hands of a skilful weaver and a clever tackler was, in general, a machine which produced a material good enough for its purpose, at a lower cost than any alternative method that had been tried. On the other hand, there were undoubtedly many things about the loom that were not satisfactory, but it was no easy task to remedy these defects in a way that would appeal to the majority of users. For, unlike many single-purpose machines, the loom, at least the ordinary loom, must be readily adaptable to the weaving of widely different cloths. The continued use of the ordinary friction let-off for example was largely due to its adaptability to varying conditions.

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* This lecture was repeated to a meeting of the Irish Section on 8th March, a report of which appears on page P63.

One good point about recent work on the loom, continued Mr. Hanton, was that it was being properly recorded and would eventually become generally available. The loom had suffered very much from the want of such records in the past. He had recently had an inquiry as to the designing of an underpick motion for a wide linen loom, from a firm which had not previously made that type of loom. He could not refer them to any really reliable published information on the subject. Contrast that state of affairs with the careful records that were being kept by the Shirley Institute and with such papers as that recently published in the *Journal of the Textile Institute* on "An Investigation of the Operation of the Loom" by Dr. Honegger, of Zurich.

Turning to the principal motions of the loom, the lecturer briefly surveyed work which had recently been done on some of these. The chief investigations carried out on *shedding* had been directed more towards improved methods of using the existing mechanism than to improving the mechanism itself. Difficulties experienced in weaving cloths like poplins had led to study of the best methods of drawing-in, denting, and leasing, in order to get the best cover and the least reed marking of the cloth. From these investigations it would appear that satisfactory cover was only secured when the tensions in each shed line, and particularly the top shed line, were as uniform as possible. Two ends separated from each other by a reed wire must not be tighter than the others. Two ends both tighter than the average and one on either side of a reed wire would show a reed mark between them when woven. As to the best number of shafts, ends per dent, and system of leasing, one expert recommended for ordinary poplins, six shafts operated by special tappets, giving "split" shedding, the ends leased three and three, drawn in with the usual skip draft, 1, 4, 2, 5, 3, 6, and dented to give the least number of shafts between those carrying ends on adjacent sides of a reed wire. Split shedding, in which the different heald shafts were moved at slightly different speeds, so as to reduce the congestion in the reed when the ends were passing each other, had been in use for many years. It was first brought to his notice, said the lecturer, by Mr. J. W. Pennington, of Burnley Technical College.

It was generally agreed, said Mr. Hanton, that the lift of the heald shafts should be proportional to the distances of the shafts from the fell of the cloth. But although this gave clean shed lines, it would not, by itself, give uniformity of tension in the threads of one shed line, the ends on the back shafts being tighter than those on the front shafts. Again, the custom of ending the heald shaft dwell and beginning the change some considerable time before the back centre crank position and long before the shuttle left the shed, was being investigated. The object of the early start of the heald change was generally assumed to be that of giving sufficient time for the change, so that excessive warp breakages would not occur. The evidence on which this was based seemed doubtful. The shuttle must clear the shed in good time to get home in the shuttle box early enough to lift the warp protector and prevent damage to the warp, but there seemed no good reason for curtailing the time for the shuttle passage by starting the heald change so early as usual. An increase in the dwell would slightly decrease the shed opening at beat-up, if the beginning of the dwell was unchanged and so might have a bad effect on the "cover" of the cloth.

In *picking* also, work had been done on the most suitable size and type of supply package, and the reduction of tension variations in the weft due to cop-end effect. The Shirley Institute had made a valuable contribution to knowledge of the theory of the picking motion and suggestions for improvements. They had explained a phenomenon which made the design of a picking motion, to give a certain shuttle speed, a very difficult matter. If a loom were turned over slowly, the shuttle was picked out at a speed which could readily be measured with fair accuracy. But if the loom were now run at its normal speed, the shuttle speed would not be proportionately increased; it would be much higher than that calculated when the loom speed was low. This was due to the flexible nature of the medium for the picker—*e.g.* the picking strap, and this was a factor very difficult or impracticable to allow for exactly. In the past, trial-and-error methods in finally fixing the design of the picking tappet had been used. Now, by means of experimentally determined factors, due allowance for this could probably be made and a given design of picking motion could be depended on to give a definite shuttle speed.

The problem of using larger weft packages had become acute recently owing to the introduction of the "more looms" system The larger packages had obvious advantages but also serious drawbacks which had been the reason for the adoption of the comparatively small packages generally in use. Large mule cops were more liable to break during weaving than small ones and a lower loom speed had to be used when the cop size was increased. The cost of spinning the larger cops was slightly greater than that of small cops, chiefly on account of the greater floor space required for a given production. Again, the "cop-end" effect or increase of weft tension near the end of the cop, became greater with increase in the cop diameter and especially with increase in the length of the cop. Finally, any considerable increase in the size of the cop required an increased size and weight of shuttle and often some alteration to the shuttle boxes. The method of rewinding weft on pirns or tubes was, in most respects, the best method of providing a long length of weft in the shuttle and it was a pity that the cost of the process was so high that, under existing conditions, it was difficult to justify its adoption.

A valuable contribution to the problem of providing a shuttle to overcome many of the defects commonly found in shuttles was the Richmond shuttle, invented by Mr. H. Richmond, of Preston. This does away with the common trouble with shuttle tongues by substituting for the usual split-and-movable tongue a solid one made in a piece with the shuttle tip. By an ingenious release, the pirn could be rapidly inserted in or removed from the shuttle and, once in, it remained rigid and in correct alignment. The shuttle must be used with rewound weft or with ring weft spun direct on suitable pirns Mr. O. Shimwell, the inventor of the Gawsworth loom, had adopted weft packages very much larger than those commonly in use. This had entailed the use of very large shuttles, and to get over the difficulties attending the use of these the inventor had perfected his "controlled shuttle" attachment. Not only was the shuttle a large one, but it had been put under control during its passage between the shuttle boxes, the control effectively preventing the shuttle from leaving the reed or the raceboard. A very useful piece of work had been done by the Shirley Institute in investigating the weft tension in shuttles and especially the "cop-end" effect or increased tension on the weft when the cop in the shuttle was nearly exhausted. This increased tension, which might be as much as ten times the tension in the middle of the cop, was responsible for excessive weft breakage near the cop-end, and it also affected the width of the cloth and the closeness of the picks. These tension variations, which had been known to exist for a long time, had now been fairly accurately measured, and the effect of any suggested cure could readily be measured also.

Beating-up of the weft was an operation, said the lecturer, which had had less consideration than others in weaving, one of the chief reasons for this being the difficulty of varying the conditions. To alter the speed of the reed during beat-up, without changing anything else, entailed a different construction of the slay or a different method of driving it. Investigations by F. Stein, of Stuttgart, would appear to have upset another widely-held belief about weaving, that the faster the reed was moving when near the beat-up position, the better. The effect of fitting short connecting arms to the loom, for example, was to slow down the slay when the crank was near the back centre, which was beneficial for picking; it also resulted in a higher speed of the slay when near the front centre, which was often claimed to give a better beat-up. Stein found that even a small increase in the time for the beat-up resulted in a marked improvement in the appearance of the cloth and that the slower the reed was moving during beat-up the less the force was required to perform the operation.

The *let-off motion* of the loom continued to offer an attractive field to inventors. During the past few years more than one good automatic let-off had been introduced, such as the Shirley constant tension let-off, developed at the Shirley Institute. This motion retained weighting chains on the beam ruffles, although the weighting and chain arrangement was somewhat different from that on the ordinary let-off. A floating roller over which the warp passed was connected to the weighting system and reduced the tension on the weighting chains. As the beam wove down, the angle of the warp line passing over the floating roller changed and this resulted in more tension being taken off the weighting chains. This compensated for the reduced beam diameter and kept the warp tension constant. Another motion, the Cotton automatic let-off, used a spring instead of weights for applying tension to the weighting chains. A floating back rest automatically reduced the force applied by the spring whenever the warp tension increased.

The ordinary positive *uptake motion* was next referred to by Mr. Hanton. This was a simple and generally reliable piece of mechanism, but it had been shown to be responsible, or at any rate partly responsible, for weft barring which is a fairly common fault in poplins. The Shirley Institute had traced these faults to variations in the rate of take-up, caused by slight eccentricity of the wheels of the motion, due to inaccuracy in the boring of the wheels, and, to a smaller extent, to inaccurate engagement of the teeth of the wheels. Both of these defects should be removed by using wheels with cut teeth and it might be that such wheels would, before long, displace the usual wheels with cast teeth, at any rate for looms for good quality cloths such as poplins.

This survey, said Mr. Hanton, would be incomplete without some reference to the important matter of loom driving and, in particular, to the valuable work done on that subject by Dr. Honegger* of Zurich, who had worked out by theory, and checked by experimental tests, the variation in power required by a loom and in its speed when individually driven by electric motor. He had also compared, experimentally, the running and the power consumption of the same loom when driven by four different types of driving motor and three different methods of transmission from motor to loom. His conclusions were that "Line shaft drive cannot be technically satisfactory because completely irregular variations in speed are inherent in it". His investigation proved that "the loom exhibits considerable irregularity in its running, which it is impossible to equalise completely, either by mechanical or electrical means". The loom drive must take account of this peculiarity and reduce the irregularity as far as possible, ensuring "absolute consistency in the periodic speed fluctuations. A correctly designed individual electric drive fulfils these conditions".

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* This *Journal* 1933, **25**, T421–T434.

So far, continued the lecturer, the individual electric drive had been adopted to a very limited extent in Lancashire, and in view of the opinions expressed at the recent meeting of the British Association of Managers of Textile Works, there seemed no immediate prospect of a change of policy. Many, if not most, of the speakers were willing to acknowledge the many advantages of the electric drive, but nearly all the mill men who spoke were in favour of steam on account of its lower cost. No one was more willing than the lecturer, he said, to admit the many advantages of the individual electric drive for the loom, and to agree that, if the cost of current was not too great, it was the best driving system, but nothing was gained by making claims for it which could not be substantiated, or at any rate which had not been definitely proved. Even Dr. Honegger was not entirely free from this fault. He claimed, amongst other things, that his investigations showed "that when starting up, the first pick was correctly made under all conditions". His speed diagrams hardly bore this out, though the speed at the pick was not much below the normal speed. The speed at the first beat-up was certainly below normal. In these respects the line shaft drive was generally as good as the individual drive.

Dr. Honegger had worked out the variations in loom torque (or driving power) and the variation in speed that occurred during each weaving cycle, for a 43-in. reed-space Ruti loom, fitted with a dobby working at 175 picks per minute, and driven by a ¼-horse-power electric motor. He calculated that the speed would vary 20%, *i.e.* about 10% above and below the mean speed, when the loom was running empty, without the dobby. This he found agreed well with speed variation diagrams taken by modern recording instruments. The parts of the loom which were chiefly responsible for this speed variation were the slay and the picking, the lowest speed being at the end of the picking period, whilst the effect of the slay was alternatively to speed up and slow down the loom, the highest speeds being at beat-up and again at back centre, both times when high speed is undesirable. As already stated, it was impracticable to reduce this speed variation materially. It was desirable to do so, not necessarily to try to get absolute regularity of speed, but to approach more nearly to an ideal speed variation for the loom, which would roughly be exactly opposite to the speed variation which actually exists.

In conclusion, asked Mr. Hanton, what are some of the things to which it seemed desirable that consideration should be given in the near future ? Some of these had already been mentioned. The question of the individual motor driving of the loom might be investigated more closely, especially the claims of higher production and better cloth. General statements are useless in this connection; what was needed was definite proof. Further work was needed on the effects on the appearance and quality of the cloth, and on the weaving efficiency, of the shedding, beating-up, and let-off factors that have been mentioned. Nor was the question of the best type of weft supply by any means settled. Consideration of questions like these inevitably led to the wide subject of the types of looms likely to continue in use. It seemed probable that the loom with automatic weft supply would oust the ordinary type of loom for the manufacture of simple cloths which lend themselves to large-scale production. Should that view prove to be correct the effect on some of the work being done on weft supply was obvious. The case for and against rewinding of weft, and the causes of the low efficiencies often experienced in that process, called for an impartial investigation. The ordinary loom would doubtless continue to be used for the better quality and more intricate cloths, of which short lengths were generally required. But it would be an improved ordinary type of loom. Better design and construction of all the parts was necessary if less faulty cloth was to be woven. An enormous loss of time and money must have resulted, even in the last few years, from poplins and artificial silks alone being faulty through defective loom mechanism. For the design of such improved looms, several things were essential. More experimental work was yet required on existing looms; a good book on loom design would be invaluable; and the training of the loom designer must be carefully considered.

Mr. Hanton was accorded a hearty vote of thanks for his very interesting lecture.

Midlands Section

On Wednesday, March 21st, a party of members from the Midlands Section made their final, and what was probably their most interesting visit of the season to the well-known carpet manufacturing mill of Messrs. Brintons Ltd., of Kidderminster. The party was met by the Secretary of the Company, Mr. A. L. Jerome, and were then escorted through the mill, where the processes were inspected and explained from the raw wool to the finished product *via* the woollen spinning plant for the Axminster carpets, and the worsted spinning for the Wilton qualities. Great interest was shown in the weaving sheds where looms of various widths were producing both Axminster and Wilton carpets. The party was also allowed to visit the Engineering department where this firm entirely construct their own looms.

The Honorary Secretary requested Mr. Jerome to convey the warm thanks and appreciation of the party to his directors for this most interesting visit

Irish Section

A meeting of members of this Section of the Institute was held in the Municipal College of Technology, Belfast, on Thursday, March 8th, when Mr. W. A. Hanton, M.Sc. Tech., of Manchester, contributed a paper entitled "Recent Work on the Power Loom". In the unavoidable absence of Mr. M. C. Andrews, M.R.I.A., F.T.I., the chair was occupied by Mr. J. D. Athey, General Secretary. There was a good attendance of members and friends and Mr. Hanton delivered a most interesting address dealing with many recent investigations regarding the design of the loom and power consumption. The lecture was illustrated by lantern slides and at the close of the address there was a useful discussion. A vote of thanks to the lecturer, proposed by Mr. J. McClenaghan, seconded by Prof. Bradbury, B.Sc., F.T.I., was carried with acclamation.

INSTITUTE MEETING AT TROWBRIDGE

At the Wilts County Textile School, Trowbridge, on the evening of March 26th, a meeting promoted by the Textile Institute took place, when a paper on "Faults in Wool Fabrics" was contributed by Mr. W. E. King, F.T.I., Lecturer in Textile Testing at Bradford Technical College. The meeting had been organised by Mr. J. McIsaac, A.T.I., Principal of the School and there was a good attendance, the meeting being presided over by Mr. F. V. Clark, Chairman of the Textile Committee. Mr. King submitted a large selection of specimens of fabrics containing faults and in some instances described the tracing of the faults. Many questions were asked and the meeting was of a protracted character. The Lecturer and the Institute were warmly thanked. The General Secretary (Mr. J. D. Athey) returned thanks for the interest manifested in the proceedings, referred to the Institute's objects, and recommended students to aim at the higher qualifications available by means of Institute membership.

NOTES AND NOTICES

Annual Conference at Grange-over-Sands

Available particulars in relation to the Annual Conference of our Institute, to take place at Grange-over-Sands in the latter part of Whit-week (23rd to 25th May inclusive) have now been issued together with the final Attendance Form. A list of papers and authors and a brief outline of the whole programme of events have also been issued. Members are reminded that they may invite accompanying friends, and booking of hotel accommodation may be made by request to the General Secretary of the Institute. The response to the preliminary announcement sent out a few weeks ago has been excellent and bookings already effected at this early stage are considerably more numerous than in previous years. A good attendance appears to be fully assured and, in view of this prospect, it is advisable that members contemplating attendance should return the form indicating their requirements at the earliest possible date. The proceedings will commence with assembly on the Wednesday afternoon and in the evening there will be a Reception by the Chairman of the Grange Urban Council (Lieut.-Col. A. T. Porritt, J.P., C.C., Sheriff of the County Palatine), and members and officials of the authority named. On the Thursday morning the Conference will open at 9.30 a.m. and at 2 p.m. there is to be an excursion by motor coach to Lake Windermere with a motor-launch outing on the Lake from Bowness to Waterhead. In the evening the customary Institute Dinner will be held and it is hoped to arrange for the presentation at this function of the Institute's Warner Medal to the Research Staff of the Shirley Institute of the British Cotton Industry Research Association, in honour of literary contributions to the *Journal* of the Institute. On the Friday morning, the Conference will be resumed and in the afternoon, at 2.45 p.m., the Annual Mather Lecture is to be contributed by Mr. A. P. Young, O.B.E. (Manager of Rugby Works of B.T.H. Co. Ltd.). The title of his lecture will be "Industrial Leadership". The proceedings will terminate after the lecture on the Friday afternoon with afternoon tea by invitation of the Council of the Institute.

Council of the Institute: Election

Nominations in respect of the election of ten members to the Council of the Institute were announced at the April meeting of the Council. The whole of the retiring members, with the exception of Major W. Vernon, F.T.I., of Stalybridge, who had intimated withdrawal, are nominated for re-election, whilst there are additional nominations to the number of 10—a total of 18 candidates. It was ordered that ballot papers should be posted on April 26th, returnable on or before Monday, May 14th. The result of the ballot is to be declared at the Annual General Meeting, at the Institute, on the afternoon of Wednesday, May 16th. At this meeting also, the election of President and three Vice-Presidents will take place. As already announced, the President-elect is Sir Thomas Robinson, J.P., whilst the Vice-Presidents nominated are Messrs. W. Frost and E. Midgley for re-election and Mr. T. Morley for election.

Obituary Announcements

Mr. R. Truesdale

It is with extreme regret that we have to record the death of Mr. R. Truesdale, an Associate of the Institute, at the early age of 43 years. As a student in textiles at Manchester College of Technology, Mr. Truesdale secured many special awards, including a Manchester City Research Scholarship for one year, awarded in 1916, whilst he had previously figured as a Drapers' Company Textile Scholar (value £85 for three years), and had secured City and Guilds silver medals in Cotton

Spinning and Cotton Weaving. From 1919 up to the time of his decease, Mr. Truesdale was employed in the important position of Chief Textile Technologist and head of the Textile Division of the Dunlop Rubber Co. Ltd., at Erdington, Birmingham. He had carried out important duties in connection with the operations of the firm named in America. His name has been associated with several patents and also a considerable amount of textile literature. As recently as October last year, when a party of members of the Midlands Section of the Textile Institute visited the Dunlop Works at Erdington, Mr. Truesdale contributed a most interesting address on motor-tyre construction.

Mr. William Marshall

An esteemed member of the Institute for many years, Mr Wm Marshall, J.P., of Cheadle Hulme, Cheshire, passed away on January 16th last at the age of 75 years. Mr. Marshall was a Fellow of the Institute of Chemistry and was actively identified with many other organisations of a similar character, whilst he served on several committees of the British Cotton Industry Research Association. A Yorkshireman by birth, he was in charge of a dyehouse when quite a young man, and, from 1888 to 1891 studied chemistry under Professor Clowes at the University College, Nottingham. In 1893 he became head of the Chemistry and Dyeing Department at the Rochdale Technical School. In 1902 he was appointed by Messrs. Clay, of Cheadle, and later proceeded to service with the firm of Messrs. Samuel Heap & Sons Ltd., Rochdale. In 1926 he was elected a Vice-President of the Society of Dyers and Colourists. His best known work was in connection with commercial dyeings on cellulose acetate material and he was a pioneer in the use of ramie for incandescent mantles. Mr. J. R. Hannay, writing in the *Journal of the Society of Dyers and Colourists* (April) concludes a reference to the late Mr. Marshall as follows—"A man of broad culture, sterling rectitude, kindly disposition, and shrewd perception, the community of Societies which he served with unselfish devotion are richer for his labours and example and poorer by his loss".

West of England

Recent requests to the Institute for the promotion of meetings of textile technological interest in the West of England indicate a welcome movement in the area in question. On the evening of March 26th, a successful meeting of students and others took place at the Wiltshire County Textile School at Trowbridge in connection with which Mr. J. McIsaac, A.T I , contributed an excellent effort in the local organisation of the event. Mr. W. E. King, F.T.I., Lecturer in Textile Testing at Bradford Technical College, kindly accepted an invitation to Lecture on "Faults in Wool Fabrics", and he exhibited a comprehensive selection of specimens which were examined with keen interest. Indeed, the discussion which followed the lecture was of an unusually protracted character. Mr. M. F. V. Clark, J.P., occupied the chair and spoke in terms of warm appreciation of the lecturer's effort. A further request for assistance in regard to lectures has been received from the Director of the Technical Schools at Stroud, and the Finance and General Purposes Committee have approved the reply sent offering assistance as far as may be convenient and useful. Membership of the Institute is at present very limited in the West of England but the movement referred to should stimulate interest in our organisation. The Midlands Section of the Institute has commendably endeavoured to widen its sphere of influence of late and visits have been promoted to works as far afield and as widely apart as Congleton and Kidderminster.

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application—

No. 106—Damask Designer desires similar position or Assistant Managership. City and Guilds Full Tech. Certificate in Linen Weaving. Eleven years' experience as designer and three years' experience as evening teacher.

No. 113—Young man seeks position as Assistant to Weaving Manager or to Weaving and Finishing Manager (woollen and worsted).

No. 115—Assistant Manager desires position as Weaving Manager or Assistant Manager. Associate of Textile Institute, Bradford Technical College Diploma in Cloth Manufacture, and City and Guilds Final Certificate in Woollen and Worsted Weaving.

No. 116—Young man desires position as Assistant Designer or Assistant Woollen Mill Manager. City and Guilds Certificate in Woollen and Worsted Weaving and Designing. Four years' experience as Assistant Designer, two years as Assistant Manager, one year as Designer-Inside Manager.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (December issue of this *Journal*)—

FELLOWSHIP

FRIEND, Reginald Henry (Manchester)
GREENWOOD, Henry (Radcliffe)
MARSH, John Thompson (Manchester)
MICHIE, John Livingston (Hawick)
RHODES, Oswald Stanley (Manchester)
SUTTON, George Donald (Preston)

ASSOCIATESHIP

CROASDALE, Harold Owen (Colne)
GROGAN, George (Manchester)
JEROME, William (Bradford)
LEE, Stanley (Bradford)
SMITH, Colin (Keighley)

Institute Membership

At the *March* meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—Cyril Kisby, 18 West Cromwell Road, London, S.W.5 (Student, Royal College of Art); Edgar Priestley, 4 Montague Street, Little Horton, Bradford (Textile Chemist and Analyst, Bradford Conditioning House); N. P. Neemuchwala, The Hira Mills Ltd., Ujjain, Central India (Assistant Carding and Spinning Master); Marc A. Winandy, 43 Edward Street, Bradford (Wool and Mohair Importer). *Junior*—Albert Firth, 1 Brighton Street, Shipley, Yorkshire (Clerk, Worsted Spinners' Sample Room).

At the *April* meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—Jas. A. Brooks, Cannanore, N. Malabar, South India (Mill Manager, Cotton Weaving); F. C. Charnock, B.Sc.Tech., A.M.C.T., Torweston, Williton, Somerset (Collar Manufacturing); M. Perk, 3 Burrow Street, Bradford, Yorkshire (Director, Maxwell Perk Ltd., Wool Merchants).

REVIEW

The Lancashire Cotton Famine 1861-1865. By W. O. Henderson. Published by Manchester University Press. (Pp. vii+178. Price 8s. 6d. net.)

This is an interesting book which, published at the present period and read in the light of the events of recent years, provides in itself a sound argument for the study of economic history. Obsessed by the present, we are apt to forget that economic crises are not phenomena confined to post-war years, but that they have frequently arisen throughout the ages. It is, therefore, opportune at a time when the Lancashire cotton industry is passing through a period of strain that an analytical study of an earlier crisis should be made, so that we may retain our sense of proportion. Mr. Henderson's book has a further claim to our interest, in so far as he refutes the prevalent idea that the Cotton Famine was due solely to the American Civil War and shows that over-production and the need for reorganisation within the industry itself contributed important factors to the general depression. The lesson is obvious. The method of treatment adopted by the author, though lacking in continuity, has enabled him to treat of such aspect in some detail. Each chapter deals, as an individual study, with the various factors, commercial, social and political, of the period. Under these circumstances a lack of unity in the book as a whole is perhaps inevitable.

Possibly more reference could have been made to the effect of the Cotton Famine on industries dependent on the manufacture of cotton goods. True, on pages 9 and 10 the increased output of linen, worsted and woollen goods is mentioned, but, apart from a reference on page 45 to the export of coal to Egypt, the serious effect on the coal trade in the area is not discussed. On page 54 Mr. Henderson points out that, amongst many blunders made by the Government's Special Commissioner sent to inquire into the relief of distress, a serious mistake was made at Macclesfield due to confusion arising from unemployment figures relating to cotton and silk operatives respectively, yet the author himself has made a similar error. On page 69 he writes—"The landed gentry helped too (i.e. in the relief of distress amongst the operatives). The whole parish of Poynton (near Stockport) with a population of 2,050 was relieved by the owner, Lord Vernon." This is a true statement of fact, but it must be remembered that this parish at that date, and until very recent years, was almost entirely dependent upon the coal mines owned and worked by Lord Vernon. There have never been cotton mills in the village and, apart from a few operatives, chiefly women, working in mills in Hazel Grove, Marple or Bollington, the population had had no direct contact with the cotton trade. On the other hand this one instance must have been typical of many throughout Lancashire and its borders, in which acute distress amongst the miners supplying coal for the cotton factories had to be relieved.

The book is admirably documented and there is an extensive Bibliography, which is itself divided into sections according to topic and type of source. There is also an appendix containing statistical data, though for the reader unacquainted with the manufacture of cotton, reference to and comparison with the more recent figures would probably be useful. F. M.

GENERAL ITEM

FEDERATION OF TEXTILE SOCIETIES

The seventh annual meeting of delegates representing the various affiliated organisations took place at Halifax, by invitation of the Halifax Textile Society, on Saturday, March 24th. In the morning, the officers and delegates visited the works of Messrs. John Mackintosh & Sons Ltd. and the Halifax Corporation Waterworks Filter House, after which luncheon was served at the Alexandra Hall. Councillor W. Brenard, J.P. (President of the Halifax Textile Society), occupied the chair and was supported by the Mayor of Halifax, Councillor F. A. Leach, J.P.; Messrs. H. E. Brearley, Chairman of the Halifax Textile Society; J. D. V. Mackintosh; E. P. Brook, Waterworks Engineer; A. R. Boeree, M.A. Principal of the Technical College; H. Turner, F.T.I., Head of Textile Department of the College; J. Hill, Head of Weaving Department; W. L. Stuart; Councillor T. W. Hanson; Councillor P. N. Whitley; E. M. Roberts, President of Federation; W. Munn Rankin, M.Sc., Principal of Burnley Technical College; J. W. Wolstenholme, Past-President of Federation; G. H. Thompson, F.T.I., President-elect; J. D. Athey, Hon. Secretary; and J. Wolfenden, Hon. Secretary of Halifax Textile Society.

Councillor Brenard introduced the Mayor of Halifax, who extended a hearty welcome to the delegates, Mr. E. M. Roberts responding as President in a speech which contributed interesting records of the early history of cloth manufacture in the Halifax district. Mr. Roberts warmly thanked the Halifax Textile Society for their kind hospitality to the Federation delegates.

On the motion of Mr. G. H. Thompson, seconded by Mr. W. P. Richmond, hearty votes of thanks were accorded to Messrs. John Mackintosh & Sons Ltd. and to Mr. E. P. Brook (Waterworks Engineer).

The annual meeting followed. Mr. Roberts took the chair and at the outset moved the election of Mr. G. H. Thompson as President for the ensuing year. Mr. Kershaw seconded and the motion was carried unanimously.

In accepting election Mr. Thompson said he felt highly honoured. Critical times appeared to lie ahead for textile societies, as students were not being attracted to textiles as formerly. Nevertheless, he was convinced that the situation represented only a passing phase born of the deep depression in trade. They had heard a good deal of late, he said, about over-production and of reduction of employment effected by science and technology. The latter suggestion was entirely contrary to facts. Science and technology had contributed to greater employment. The trade depression was a social and not an industrial phenomenon. It was lack of clear thinking which produced the idea that a halt should be called for in science and technology until the social conditions caught up. What would the clothing of the peoples of the world be like to-day if the spinning wheel had remained in general operation ? He thought they might take courage for the future, believing that industrial adversity was an abnormality.

The Report of Committee of Management, with accounts duly audited, were presented and adopted.

The election of Committee followed. For Yorkshire and Leicester areas and the Textile Institute representatives, the nominations received met the requirements. In the case of the Lancashire area, there were five representatives nominated for four vacancies and a ballot was taken. The election of Committee was then declared as follows—Lancashire—C. E. Anderson (Ashton), F. Chadwick (Preston), W. P. Richmond (Nelson), J. W. Wolstenholme (Rochdale); Yorkshire—N. Collinson (Batley), H. Holroyd (Huddersfield), J. Wolfenden (Halifax); Leicester—J. H. Lenton; Textile Institute—H. Nisbet (Lancashire Section), A. Saville (Yorkshire Section); Past-President (*ex-officio*)—E. M. Roberts.

Mr. Athey was re-elected Hon. Secretary and Treasurer for a further year, and Mr. W. Kershaw was re-elected Hon. Auditor.

After considerable discussion and on the proposition of Mr. E. M. Roberts, seconded by Mr. Wade Hustwick, it was decided to adopt the prize scheme as set out below.

An invitation to visit Belfast for next annual gathering was unanimously accepted with thanks to be communicated to the Belfast Textile Society.

An address under the title of "The Growth of Halifax" was given by Councillor T. W. Hanson, in which he traced the history of the textile industry in the Halifax District, and made particular reference to the Piece Hall and its associations. The district specialised in cloth production long before the Flemings came to this country. The introduction of canals was as important as the later introduction of railways, if not more, for a canal boat drawn by a single horse effected transport equalling 600 packhorses.

A hearty vote of thanks was accorded Councillor Hanson, after which an inspection of the Textile Department of the Halifax Technical College took place, and afternoon tea was served.

Prize for Paper or Lecture—The Federation offer a prize of £5 value for the best paper or lecture on a textile subject contributed to an affiliated Textile Society during the session 1934-35.

The paper or lecture must have been delivered at a meeting of a textile society, the contributor being a member of the society or of another affiliated body.

Members engaged as full-time teachers are not eligible.

Each society is invited to select one paper so contributed and forward a copy to the Federation for adjudication.

The decision of the Committee of Management of the Federation as to the award of the prize shall be final.

Papers submitted should reach the Hon. Secretary of the Federation on or before 30th April 1935.

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PROCEEDINGS

THE MATHER LECTURE

INDUSTRIAL LEADERSHIP

BY A. P. YOUNG, O.B.E., M.I.E.E., M.I.A.E., F.I.I.A.

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SECTION 1—A SURVEY OF THE PAST

1—Foreword

Life is a great adventure in which a few restless spirits are more venturesome than the many. And history seems to show that the courage and vision of the venturesome minority has made the adventure worth while for the great majority. The spirit of adventure is as old as life itself. In the dim distant past, separated from the present by æons of time—Sir James Jeans puts it at 300,000 years at least—this spirit never ceased to urge the small band of humans forward along the tortuous path of uncertain existence. Through countless generations this impelling and divine urge just enabled the human race to maintain a balance favourable to life and continuity, in an amazing combat with the forces of nature. Thus at last our progenitors brought the struggle to the point of time which marks the beginning of the era of recorded history—a mere speck on the time chart measuring the prolonged process of human evolution on this planet.

In glancing at this dim but miraculous picture of human turmoil and strife through tens of thousands of years, we can in imagination discern the slow development of the power of Leadership—that ever dominant and controlling force which influenced families, tribes and ultimately nations, to overcome all obstacles which hindered living and growth. It energised a ceaseless striving to reach a higher state of existence. The dynamic power of which I speak originated, in primitive ages, within the family circle, being embodied in the parents who fed and protected their young. The offspring obeyed mainly through fear—fear of their parents, and fear of hunger, cold, cannibals and wild beasts. H. W. Nevinson in a fascinating little book entitled "The Growth of Freedom" which was written just before the war, says—

> "In the prehistoric family various forms of authority must have existed in germ, and to-day, even in the most primitive species of mankind, we cannot discover or imagine human life coming to maturity without them."

The primitive families of that distant age naturally developed into tribes, to aid them in their struggle for food and safety. Leadership of the tribe automatically went to the member who was strongest and best able to lead the tribal forces in battle with other tribes, and to defend them from attack. When victorious, he was joyfully endowed with special honours in keeping with the primitive conditions of the age. With the passing of time the sceptre and the crown appeared, and Kingship was at last created.

Thus we can picture the growth of the power and prestige of the Leader over a time-span stretching far back into unrecorded history. Many great Leaders of whom we know much strode across the world stage of recorded history, but for the most part they were leaders of war and conquest. Because the spirit of their leadership partook of the spirit of the age in which they lived; an age characterised by two dominant forces—the force of scarcity and the force of slavery. But even so, our twentieth century civilisation owes much to these Leaders—to men like Alexander the Great, Julius Cæsar, and Charles the Great, to mention only three towering leaders of men, to illustrate this point. F. A. Wright in an entrancing life story of Alexander the Great, recently published, says—

> "Alexander was the fine flower of Greek civilisation. . . . . The effect of his conquests in widening the horizon of men's minds can only be compared to the discovery of America in the fifteenth century. . . . . To Aristotle he owed much, but he went far beyond his master when, casting aside the distinction between Hellene and barbarian, *he boldly proclaimed the universal brotherhood of man.* From that declaration of faith much was to follow in coming ages, and in the countries which he conquered and organised, Christianity found the soil already partly prepared."

Be this as it may, I believe that our future civilisation will owe a greater debt to the thinkers and religious teachers of that era when the Eastern Basin of the Mediterranean was the centre of inspired thought and human activity, than to those titanic war leaders and Empire builders whose exploits form the backbone of history. The profound philosophical thinking of Plato and Aristotle still has a message for those now living. And as we travel through this century the divine teaching of Christ must have an ever-increasing influence for good on human life and progress, if our civilisation is to endure.

2—The Growth of the Scientific Era

Now this spirit of adventure inherent in man may lead either to great achievement or to great disaster. In any event it is inseparable from great risk. When that little band of adventurers, to whom we owe so much, marched boldly forward to explore that immense and uncultivated region where the methods of scientific thinking and inquiry have their habitation, no one could have foretold of the wondrous achievements, or of the appalling disasters, or of the tremendous risks which would be encountered on the journey into the unknown.

There were great scientific thinkers in Ancient Greece, notably Archimedes, whose meditations were the genesis of the science of hydrostatics, and Thales, whose researches with amber started the science of electricity on its beneficent career. But no real scientific progress was made until the thirteenth century when Roger Bacon initiated that era of exact scientific inquiry and analysis which is now unfolding itself—after a lapse of nearly 700 years—with such astonishing and disturbing rapidity.

The banner of scientific progress once unfurled was never lowered. As the centuries rolled by many pioneer workers in many lands gave their allegiance to the great cause which it signifies. Little headway was made until the period of the Renaissance when the increased political stability and improved conditions of living created an atmosphere favourable to real and substantial progress. Thus we can picture the banner being held high by Dr. Gilbert, Francis Bacon, Gallileo, and Sir Isaac Newton in the sixteenth and seventeenth centuries.

During the eighteenth century, the aspirations of those who had struggled to keep aloft and unsullied this banner of progress were fulfilled. New followers in many countries were attracted to the colours, and the few stragglers were expanded into a disciplined company—the first unit of that vast international army of scientific investigators which is now blazing the trail of human advancement. In America there was Benjamin Franklin, whose researches on the nature of electricity were of outstanding importance, whilst in Italy, Galvani and Volta were also engaged in unravelling some of the mysteries of the electrical era. In England, the great Henry Cavendish was holding aloft the scientific name of England by his pioneer work as a chemist and physicist. And nine years before the century closed the immortal Michael Faraday was born. His subsequent labours made the scientific prestige of England tower above all nations in the first half of the nineteenth century, and his major contribution opened wide the door to the electrical era.

3—The First Industrial Revolution

In the latter part of the eighteenth century, the Industrial Revolution began in England, and the members of this great Institute whom I have the honour to address, must derive stimulus and encouragement from the reflection that the hand of destiny chose Lancashire as the birth-chamber of this new era. This epoch-making occurrence resulted from the fusion of two progressive impulses—one directed to improving the machinery used in the cotton trade, and the other seeking a power unit which could drive the machines.

In 1767 James Watt invented the steam engine and made available to mankind for the first time in human history a power-machine for doing work hitherto done by man and beast. This was a great event, because his engine found immediate application in many directions; but more important still, it gave to the human race the vision of an era when power-driven machines could do the work of the world. Contemporaneously with this progressive movement in the use of mechanical power there was a flood-tide of creative thought in the Textile Industry directed towards improving the mechanisms of production. Richard Arkwright and James Hargreaves had taken out important patents in 1769 and

1770, whilst ten years later Samuel Crompton made public his invention of the spinning mule when only 27 years of age.*

Many years elapsed before this power-driven mule became absorbed in the factory system, but Arkwright was quick to perceive the significance and value of Watts' invention, and designed his machines so that they could be power driven. Richard Arkwright also organised the whole process of transforming the raw cotton into yarn, so that the use of his machine started the factory system in the cotton industry. Thus did the industrial revolution begin towards the end of the eighteenth century. Industry has never ceased to evolve and revolve during the past 150 years. Indeed the process of evolution has been so speeded up since the beginning of this century that it has produced by its reactions, within very recent times, a second industrial revolution in which we are completely engulfed.

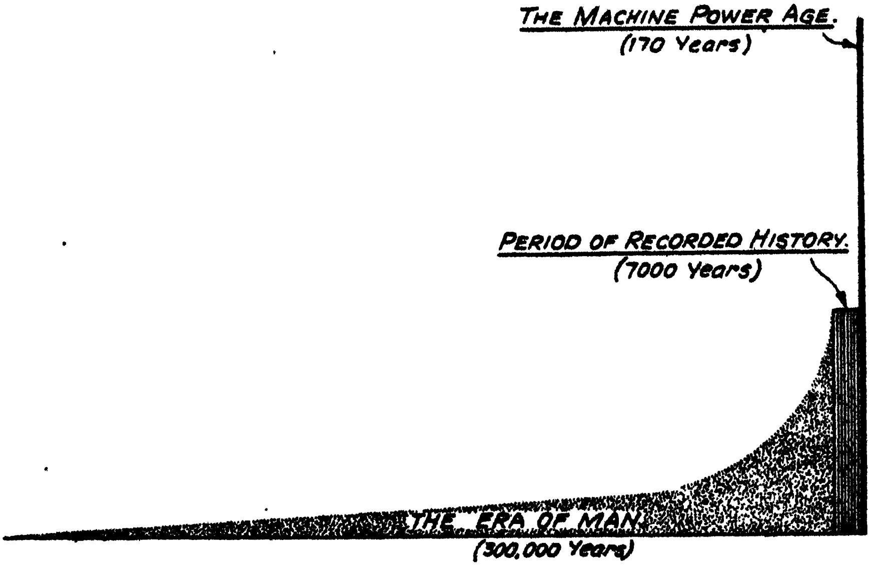

Chart showing short duration of Machine Power Age in relation to the prolonged ERA OF MAN.

FIG. 1

4—The Machine-Power Age

During the past three decades, the age of power-driven machines has received enormous impetus from the phenomenal evolution of the electrical art. In the short time-span of just over six generations, the age of power-mechanisation has produced an amazingly complex industrial structure which is now intimately interwoven into our daily lives. It is desirable, when analysing a difficult problem, to view it in right perspective. In this spirit let us glance at the diagram in Fig. 1 which shows the present machine-power age (of 167 years duration) on a time chart in proper time-relation to the period of recorded history (7,000 years) and to the much greater time span (300,000 years) measuring approximately the duration of human life on this planet. The striking fact revealed by this diagram is that the period of mechanised industry corresponds to a thin line at the end of the time chart—a line actually covering something less than $\frac{1}{2000}$ of the total time cycle ! !

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* See "Industrial Lancashire prior and subsequent to the invention of the mule", by G. W. Daniels, M.A., M.Com. (Mather Lecture, 1927).

It is interesting to reflect that up to the beginning of the mechanised industrial era, the chief characteristics of human life were—Scarcity, Strife, and Slavery. With the advent of the power-driven machine, democracy was born and humanity entered a new era leading ultimately—as has happened in very recent times—to the potential displacement of scarcity by plenty. Almost coincident with the birth of this new age, the slavery of man to man received its final deathblow mainly through the Methodist movement. A. N. Whitehead in his "Adventures of Ideas"—one of the greatest books of recent times—says—

> "They (the Methodists) made the *conception of the brotherhood of man, and of the importance of men a vivid reality.* They had produced the final effective force which hereafter made slavery impossible among progressive races."

Thus for a relatively brief period, there has been a wonderful transformation in the dominating characteristics of human affairs. The era of Scarcity—Strife—Slavery is being replaced by an era of Plenty—Democracy—Freedom. This transformation in the moulding forces of our civilisation illustrates the natural slowness of the fructification of progressive ideas. Again quoting A. N. Whitehead—

> "So modern Democrats, in the nineteenth century, nerved themselves to face the question of slavery, explicitly and with thoroughness. . . . Two thousand years had elapsed since the foundation of Plato's Academy, since the reforms of the Stoic lawyers, since the composition of the Gospels. The great programme of reform bequeathed by the classical civilisation was achieving another triumph."

I dwell on this tremendous change in the conception of human values—a change which practically coincided with the beginning of the industrial machine-power era—to emphasise a vital consideration. With the termination of the era of man's slavery to man there began a new epoch of machine-power industrialisation in which man became in large measure a slave to the machine. This condition still exists, and one of our immediate problems is to release man from this bondage, by bringing the working and control of the machine into subjection to those divine impulses of the human mind and spirit which alone can direct the faltering footsteps of humanity along the path of peace and enlightenment.

The task is hemmed in with great difficulties arising chiefly from those traditional forces which are now supporting—whether we like it or not—the present state of society. A solution can only be found by a process of evolution, hastened, maybe, by the application of stimulating but intelligent thought and action. In working out our economic salvation we shall have to project a new mental outlook on to this intangible, but highly valuable, possession which we call democratic freedom. In a phrase, it must suffer a kind of metamorphosis in sympathy with the tremendous transformation in human affairs which is now being experienced as we move, somewhat abruptly, from the prolonged age of scarcity to the new and "still-born" age of plenty.

SECTION 2—THE DAWN OF A NEW ERA

I have hastily sketched a picture of past events to provide a background, and to create an atmosphere, both in harmony with the approach I desire to make to my main theme. At this vital moment in human history all peoples are seeking to secure greater contentment of mind and spirit, and improved material conditions. The national battalions marching steadfastly along their separate paths of evolution have suddenly discovered that the magic influence of the scientific mind has caused a confluence of the many paths on to a broad highway leading to a common goal and purpose. The national battalions have now become units in an international army. It is the supreme duty and responsibility of leadership to ensure that this army can march with triumphant joy, both of body and spirit, along the ever widening road of world progress and mutual service.

Leadership has been defined as "the quality of getting things done, not by the whip of external compulsion, but by the engendering of an inner urge and willingness on the part of others to do it." A pioneer in that vast realm of creative thought which permeates, inspires, and ultimately directs the impulse to human progress is not necessarily a leader in the sense of this definition. He is usually a teacher, a preacher, a poet, a writer, or as has happened in more recent times, a scientific thinker and investigator. On rare occasions some of these great pioneers have possessed the faculty of leadership; but in the main, theirs has been the privileged task of creating a current of thought which others, endowed with powers of direction, could utilise to propel the ship of human progress into the ever widening reaches of contentment and service.

But the qualities demanded of leadership are rapidly changing, now that we have reached the threshold of a new era that must come as the industrial revolution passes through its second twentieth century phase. The leadership now required to direct human affairs must partake of those inspired faculties which have animated the past pioneers of creative thought, and this intangible quality must be combined with executive power which is able to generate and maintain a co-operative movement of human activity towards an enlightened goal of achievement.

The immediate task of leadership is to consolidate the position now reached; and in the process of consolidation it must give impetus to those ideas and ideals which are capable of erecting on this foundation a structure of human society that will allow the energising influence of the scientific mind full opportunity for expression and service. Thus—and only thus—can the machine-power age fulfil its great destiny, and secure for humanity a steady elevation of the material plane of existence in association with a growing recognition of spiritual and intangible values.

Make no mistake, we are on the threshold of a new area, and our individual and collective actions will in the years immediately ahead, largely determine what kind of era it is to be. It should, therefore, be helpful at this stage to examine those moulding forces, of mental and spiritual origin, that have induced the present state of seething flux, and which must inevitably influence the process of reconstruction just beginning. I would set them down as follows—

1—The Spread of Education and Scientific Thinking

The universal and rapid spread of education in conjunction with a sudden increase in world population which has practically doubled in the past hundred years. These immense changes have brought about a phenomenal increase in our knowledge of nature's laws and materials, and the wide application of scientific methods to all forms of human activity. The development of this trend is constantly being accelerated. In consequence of this the scientific research worker, the chemist, and the engineer have become key members of society. Their combined efforts have, through no fault of theirs, brought the world to the verge of chaos. It remains for leadership, in association with the steady growth of a social conscience, to adjust this wrong, and cause the untold benefits which can come from this sudden forward movement of scientific and technical progress to fructify for the full benefit of humanity.

2—Transportation and Radio

The great improvements in our methods of transportation on land, sea, and in the air, in combination with the radio art, have done much to annihilate distance and make the world a relatively small place. The closer human contacts thus engendered must ultimately create an atmosphere favourable to co-operative effort both nationally and internationally. The radio machine has opened up illimitable possibilities to the power of the human voice; a power that will ever remain the supreme and dominating influence in energising human contacts and creating mass action.

3—The Scientific Mind a Dominating Force

The emergence of the scientific mind as a dominating force in human affairs is speeding up all world activity. Mind intelligence is now quickly disseminated by the radio machine, and we are witnessing a steady acceleration of the complex process of translating thought into action.

4—The Demolition of Barriers

Barriers of all kinds are now being demolished by the on-rushing tide of scientific thought, and the result of this great unifying influence is to be seen in scientific, political, and religious spheres, but is yet to come, as it must, in economic realms.

(*a*) *Science*—The separate sciences—whether they relate to material things, living beings, or human aspirations and desires—are converging on to a common plane of thought and experimentation where there may well be evolved a universal science and philosophy. Some years ago Wilhelm Ostwald conceived for us a vivid picture of what he called a scientific pyramid "with logic and mathematics as the base; the energetic sciences—mechanics, physics, and chemistry—as the body; and with the sciences of life processes—biology, psychology, and sociology—as the apex." This figure of the imagination was shrouded in a fog of ignorance for countless ages. It is now becoming bright and clear as a symbol of progress, illuminated by the morning light of mind intelligence radiating from the dawn of a new era.

(*b*) *Politics*—In the realms of politics, the partitions which have for so long divided political parties and creeds are being punctured by the growing impact, from without, of scientific progress. The formation of the National Government in 1931 was a manifestation of this trend. Political thought and action are being impelled to rationalise around the common purpose of securing a steady elevation of the human factor. And this great problem—in fact, the only problem—is seen to become one mainly of science, ethics, and religion.

(*c*) *Religion*—In the world of religion, it is significant that Christian bodies (of different denominations) are uniting in a common desire and purpose to influence the whole process of economic and industrial reconstruction which is just beginning. The purpose of this co-operative movement is to ensure that the new edifice will be erected on an enduring foundation, constructed on the basis of those eternal truths which give life, vitality, and purpose to the Christian religion. The Christian Social Movement both here and in U.S.A. is gaining in power and influence.* I am impressed by the work which the Industrial Christian Fellowship is seeking to accomplish. Regular meetings of a mixed group comprising clergy, industrialists, and economists, are being held under the able chairmanship of the Rev. A. J Wade-Gery to give earnest consideration to those problems which are distressing the world, in an endeavour to find a balanced and Christian solution. The fact that this body is planning to hold a conference on Economic Reconstruction next year, illustrates this unifying change† in religious outlook which I desire to stress.

5—Co-operation must Replace Individualism

There is a growing realisation that intense individualism and *laissez-faire*—guiding principles of our nineteenth century history—have completely failed. Co-operation must be the dominant note in the future, and the co-operative effort must be applied, not in the selfish interests of an individual, or of a group of individuals, or of a nation, but to broad and wide human service. Freedom of thought and conscience must remain, and nothing should be done to retard the dynamic impulse to progress which comes from individual initiative and personality. But at the same time, we must recognise that the new era just beginning will demand a mental revolution from each one of us. What we proudly call Individualism and Liberty need to be transformed in harmony with an integrated impulse to progress in the direction of the common good.

A mere recital of these seemingly contradictory objectives serves to show how extraordinarily difficult the problem is, especially in this country, where our highly industrialised condition is largely the result of an *unnatural* form of evolution. It all means that we must proceed cautiously, as is our wont, along the clear path of evolution. But we must show courage at times to try drastic experiments, and we should not be afraid to accelerate the evolutionary forces when the path immediately ahead seems bright and clear.

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* See "A Christian Sociology for To-day," by Maurice B. Reckitt.

† This trend is exemplified by the recent appointment of a religious editor by a great London daily newspaper.

The responsibility of the British people is very great. I believe profoundly that we shall, by virtue of our rare ability and capacity for leadership, win through. We can accomplish this by first integrating those progressive forces directed towards balanced progress, which are germinating in that vast arena where there is free interplay of scientific, industrial, political, and religious thought. Then enlightened leadership, guided continually by the result of this integration, will be able ultimately to evolve a new economic and political system in harmony with true progress, still retaining that freedom of the individual human unit which is one of our most cherished possessions. The world is watching; and it may well be our immediate destiny as a nation to find a solution of this grave problem which the world will gladly copy.

6—The Gold Machine Needs Reconstruction

There is a widespread feeling that the gold machine as a monetary mechanism for interchanging services is functioning inefficiently. From many quarters there has arisen an insistent demand that the mechanism should be reconstructed so that it can work to serve human needs, and not in the interests of a privileged minority, in the new age of plenty now being ushered in. The machine has become dislocated through the impact of a relatively new but disturbing factor—the phenomenal acceleration of the productivity of the human unit. A glance at Fig. 2 will make this line of thought clear. Until quite recent times, the curve portraying the rise in this factor coincided fairly closely with the curve representing the growth in the world's output of gold. Because of this accidental alignment the gold machine has worked reasonably well through many generations. But the rapidly increasing divergence between the two curves makes it necessary so to modify our monetary system that the volume of currency issued by the central banks can expand in phase with the human productivity curve. The amount of money in circulation would then conform to the dynamic requirements of mind-intelligence and not to a static process of nature.

All these evolutionary forces with which I have dealt must have a determining influence in moulding the stages of progress which will mark our advance into the new era now opening up before us. Leadership if it is to be really effective, must have knowledge of, and be inspired by, these transforming influences. Because its main function all the time is, first, to integrate into operative principles all that is best in the progressive ideas continually generated by thinking humanity, and then to formulate a policy of action based on these principles. It must create an atmosphere favourable to the policy which it is intended to pursue, and then by inspiration and directive power secure a movement of the human team along the clearly visualised path at the right speed.

Leadership must be inspired by an *ideal* which gives direction to its creative impulse, and animated by an *idea* well within the range of practical achievement. The tangible expression of the activating idea must be capable of moving humanity some distance towards the ultimate realisation of the inspirational ideal. The current idea can be expressed as "enlightened teamwork objectively controlled", whilst the ideal has been reverberating down the ages—the brotherhood of man—descriptive of a state of society when all people will be brought together as a vast family, animated by a spirit of divine purpose, and actuated in all they do by a common interest and purpose. Despite the spirit of intense nationalism—surely a passing phase—which for the moment is corroding human aspiration and desire, the seeds of this great ideal, long since planted in the garden of human progress, now have a better chance than ever before of germinating to their full bloom of beauty and majesty.

I recollect many years ago being told by my brother, who was then engaged in clearing some of the forests in Northern New Zealand, that when the great trees had been hewn down and moved away, thus allowing the sunlight to penetrate into the soil, he found to his astonishment that new flowers which he had never seen before, unfolded themselves in all their glory. The seeds had lain dormant for hundreds of years, but at long last the latent powers of life and service found expression in the sunlight. Our immediate task is somewhat similar to this. We have to cut down and remove the lumber of bad tradition, unscientific methods, greed, pride, distrust, and selfishness. But when this is done, the divine light of wisdom, transmitted through that scientific mind-intelligence of which I have spoken, and brought into proper focus by enlightened leadership, will illuminate new regions hitherto shrouded in darkness. This penetration of an invisible but vitalising influence will germinate those latent and all-powerful forces radiating from the human spirit, so that human progress and happiness may take on a new grandeur which we can as yet but dimly perceive.

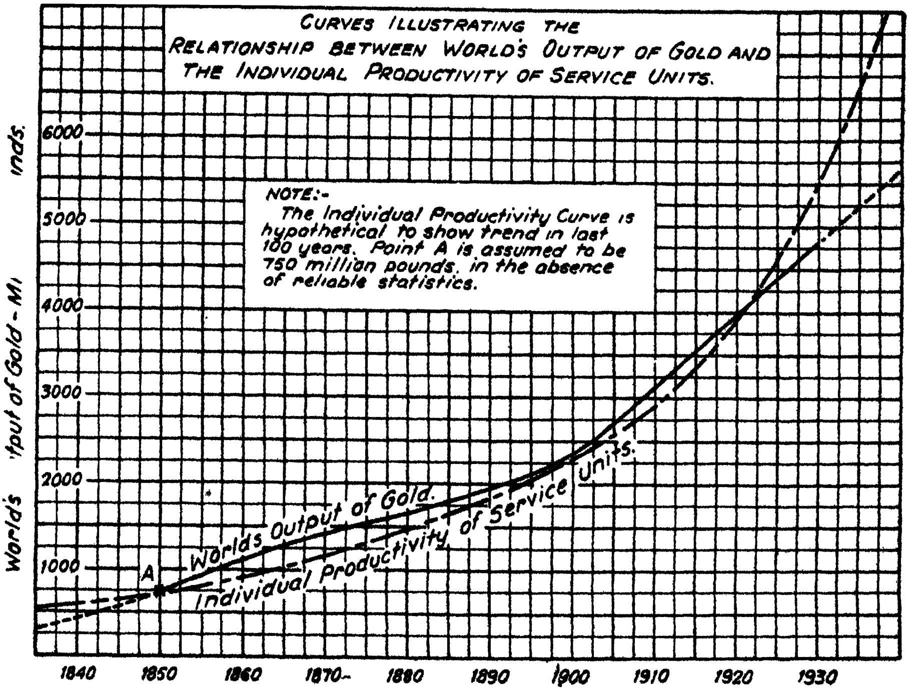


FIG. 2

SECTION 3—THE SECOND INDUSTRIAL REVOLUTION

All this is especially true of industrial leadership now that industry has become the dominating influence in human affairs. In this age of machines, industry is the dynamic and pulsating core of human activity. It is the supreme motive power within a nation, controlling the rate and direction of its progress. From this energising force radiates the wealth, prosperity, and in a large degree the happiness of the people. If this central core is right and true, then the national team can march forward triumphantly along the path of healthy progress. Should the core be diseased or suffer from mal-adjustment of its atomic structure, the retarding and evil influence radiates from it, inducing national distress, impoverishment, and ultimate decay.

But we should remember in these difficult times that industry is a very young thing. It is less than 200 years old and has hardly entered its period of childhood.

A prolonged "teething" period lies ahead, and we are now experiencing some of the growing pains inseparable from this stage of growth—an age full of wonder and inspiration to those who watch, because of the immense potentialities of good or evil which are beyond it. Our individual and collective responsibility at this critical moment is to make sure that our industrial child, pulsating as it is with life, movement, and spirit, should be so nourished, trained, and directed that it can quickly grow out of its childish ailments and with renewed vigour unfold its immense powers of human service. My main purpose in this lecture is to concentrate attention on the function of enlightened industrial leadership in relation to this beneficent work which must be speedily accomplished if our civilisation is to progress towards higher realms.

To this end let us examine the regenerative forces which industrial leadership can harness to its will and purpose so as to determine the future course of industrial evolution and reshape society in the process. These reactions can be stated thus—

1—Steady Acceleration of the Productivity of the Human Unit

The scientific mind is steadily improving the efficiency of the machine; increasing the energy consumed by it, and therefore its rate of working; and thereby producing a steady elevation in the productivity of the human unit. Fundamentally, it is the acceleration of this factor which has produced the second industrial revolution in which we are now so thoroughly immersed.

2—Steady Acceleration of the Rate of Flow in the Industrial Circuit

There is constant acceleration of the rate of flow in the industrial circuit—that circuit embracing the complete productive cycle, and stretching between mother earth and the ultimate consumer. In other words, the time interval (T) between the withdrawal of materials from mother earth and their final delivery, after being transformed into a serviceable product, such as a motor car, cotton cloth, or a radio set, is being steadily reduced.

3—The Era of Electrical Energy Supply just Beginning

There is an increasing demand for energy which is the life-blood of this mechanistic age. Because of the ease with which energy in the invisible form of an electric current can be generated and transmitted to the point of use, and then made to do useful work, great impetus is now being given to electrical developments. The electrical era is just beginning; civilisation is now advancing along an electrical path of progression. In this country the Central Electricity Board's grid system of electrical energy supply has become a potent factor in moulding our future industrial structure. Within a decade we should become the most efficiently electrified country in the world. But before this can happen, the powers of the Central Electricity Board which now only cover generation and main line transmission, must be extended to embrace distribution right up to the points of use either in our factories or in our homes, so that the wastage in the existing unco-ordinated distribution network can be eliminated.

4—Steady Reduction in the Time-lag between Discovery and its Industrial Application

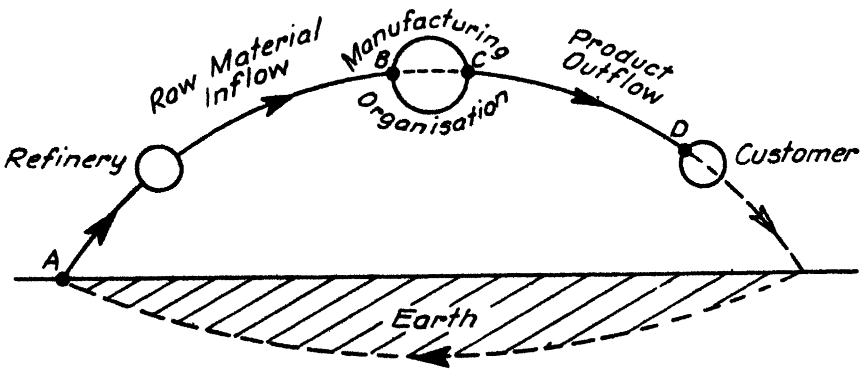
There is a steady reduction in the time interval between the discovery of a new principle, process or material, and the practical application of this new knowledge to serve human needs through industrial effort. Some 50 years elapsed between Faraday's basic discovery of electro-magnetic induction in 1831, and the inception of the electrical industry on this bedrock foundation. But now, after a lapse of only 100 years, the time-lag between the discovery of new scientific knowledge and its effective utilisation by the engineer and industrialist, is measured, not in years, but frequently in months. This striking change emphasises the important position now occupied by the research worker. His efforts in the future will transform industrial activity by creating new industries to serve human needs in diverse ways, of which we now can have little comprehension.

5—Production and Distribution Linked Together as One Industrial Problem

It is being recognised that the sequential processes in the industrial circuit are conjoined and interdependent on one another. The integration of this chain of productive operations represents the sum total of the whole industrial effort. And the rate of service flow is a function of this integration. In other words, all phases of production and all phases of distribution concerned with a particular service function are linked together as *one* industrial problem. In all our plans for industrial reconstruction we must work back to, and be guided by, this fundamental conception, if we are to secure maximum success.

6—The Function of Industry

There is a growing desire to secure a more enlightened objective for industry now that industrial leaders begin to understand that results which are economically sound can only be realised by dealing with the human units in industry on a basis that is ethically right. The primary function of industry is to render a broad human service, from which should flow, as a secondary effect, just and balanced profits. In other words, the main objective of an industry should be to improve steadily its service function.



Driving Force of Manufacturing Organisation = P
Total Resistance in Industrial Circuit = Q
Rate of Product Flow. = $\frac{P}{Q}$
Power or Status of Manufacturing Organisation = $\frac{P^2}{Q}$

$Q = r_1 + r_2 + r_3$
where, r_1 = Inflow resistance between A & B.
r_2 = Manufacturing resistance between B & C.
r_3 = Outflow resistance between C & D

Diagram Portraying Industrial Circuit.

FIG. 3

7—Planned Co-operation the Guiding Principle

There is now almost an insistent demand, coming frequently from unexpected quarters, that the guiding principle of industrial action in the future should be planned co-operation in place of disorderly and wasteful competition. This basic idea, to become effective, must be applied to groups of industrial units rendering the same kind of service. It will mean the creation of a higher control mechanism to co-ordinate and plan the activity of the associated units in a particular group, both in respect of production and distribution. And the mechanism must be so designed that it is able to maintain within the group a condition of balance, between man and the machine, as the resultant service flow is expanded through acceleration of the co-ordinated effort.

SECTION 4—THE POWER OF INDUSTRIAL LEADERSHIP

It has been my lot for the past 20 years to occupy a high executive position in one of our newest and most complex industries—the great electrical industry. When confronted with a difficult industrial problem I have found it helpful to carry at the back of my mind a picture of the complete industrial circuit, to which I have already alluded. It enables one to view in broad perspective those fundamental forces which lie at the foundation of all forms of industrial action. The industries of the world can be viewed as a complex network comprising myriads of imaginary industrial circuits all interconnected to provide our civilisation with an industrial grid capable of supplying services of all kinds in abundance.

1—Principles Governing Industrial Flow

We are beginning to understand more clearly that the rate of service flow in an industrial circuit is dependent on two main factors, just as in the analogous case of the simple electric circuit the rate of electricity flow varies directly as the driving force of the electric generator (E) and inversely as the total resistance (R). In the industrial circuit depicted in Fig. 3, the industrial organisation interposed therein provides the motive power; it is, in fact, the industrial generator. The driving force (P) is dependent mainly on the efficiency of the management factor; that is, on the management's power of leadership to guide and control the future destiny of the whole organisation as a productive and serviceable unit. The resistance (Q) on the other hand, is made up of three main components—

r_1 = The resistance interposed between mother earth and the industrial generator. This may result from enhanced and uneconomic raw material prices resulting possibly from "ring" prices, or from the efforts of an inefficient buying department. Or it may result from inefficient transportation, which is too slow and costly in its operation.

r_2 = The wasteful internal resistance in the industrial generator. Lack of directive force, complexity of routine, lack of team spirit and insufficient planning frequently combine to increase this resistance unduly.

r_3 = The resistance in the distribution portion of the circuit; that is, between the industrial generator and the ultimate customer. Resistance may here be interposed by undue selling charges; enhanced advertising expense; and discounts to a middleman which are uneconomic—anything, in fact, which tends to increase unduly the ratio $\frac{\text{selling price}}{\text{basic manufacturing cost}}$.

The total resistance in the circuit can be expressed thus—

$$Q = r_1 + r_2 + r_3$$

I believe there is good ground for completing the analogy with the electrical case already cited by stating that—

$$\text{Rate of service flow} = \frac{P}{Q} = \frac{P}{r_1 + r_2 + r_3}$$

and

$$\text{Power or status of industrial organisation as a service generator} = \frac{P^2}{Q} = \frac{P^2}{r_1 + r_2 + r_3}$$

Just as the engineer must base his creative work on well-established laws and principles, so it is necessary for an industrial leader to be guided in his fundamental thinking by the laws and principles which govern industrial flow. Newton's classical "Laws of Motion" lie at the foundation of all sound engineering. I have attempted on analogous lines to formulate three laws appertaining to the industrial circuit.

(*a*) *The Law of Inertia*—Every industrial organisation *continues* in a *state of quiescence* or *uniform movement*, except in so far as it may be *impelled to change its power of service* through the energising pressure of the industrial team acting upon it.

(*b*) *The Law of Force and Motion*—The rate of change of service flow in the industrial circuit is a direct function of the *degree* to which the *spirit of service* animates, at all parts of the circuit, the efforts of the industrial team.

(*c*) *The Law of Stress*—When *pressure from customers* acts on an industrial organisation, it is the function of industrial leadership to ensure that the *reactionary force* generated is directed to stimulating the industrial team to expand its power of service *so that a condition of equilibrium beneficial to the customer may be maintained.*

2—Industrial Leadership must Function through Teamwork

I stated earlier in this lecture that leadership is concerned with the problem of securing tangible results by engendering an inner urge and willingness on the part of others to do it. In a phrase, it can only fulfil its primary function through teamwork. The team must be wisely chosen, each member being carefully selected to shoulder the responsibility demanded of him. Co-operation and service must be the watchwords, and the united efforts of the team must be constantly directed towards an attainable goal which industrial leadership should clarify and ever keep before the vision of the team. A path leading to this goal, which is best suited to the personality and ability of the team, should be determined, and the rate of movement along this path then controlled by a series of scientifically graded objectives.

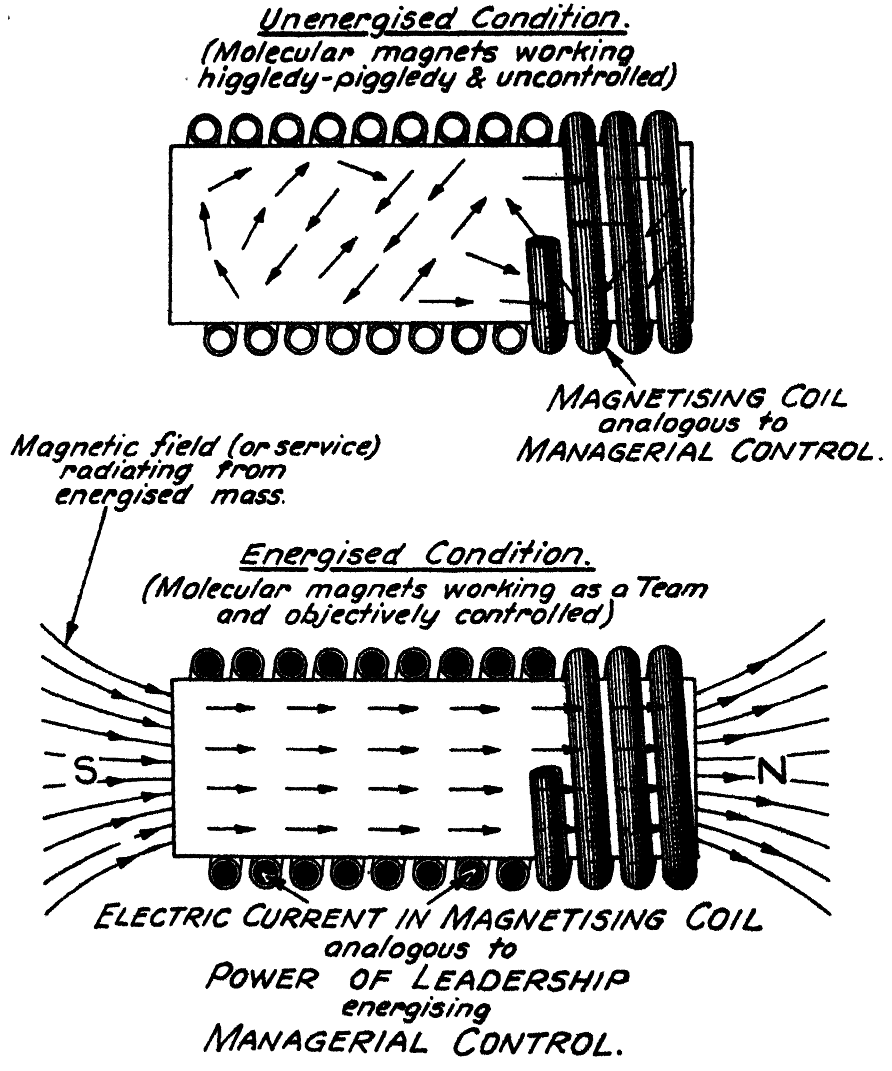
Leadership must radiate infinite patience and courage in guiding and directing the progress of the team; and all the members must be made to feel that so long as the *direction* and *rate of movement* are right, it is mathematically certain that the visualised goal, which is the inspiration of the effort, will finally be reached. And as difficulties, trials, and disappointments are encountered on the journey, the kind of industrial leadership I am endeavouring to portray will jealously watch the psychological atmosphere in which the team works, and use every means in its power to elevate the spirit of the team to those exalted heights which must be reached before great achievement is possible. Only in this way can each member of the team derive from the achievement that inner satisfaction of body, mind, and spirit which is his lawful right, and absorb these tangible gains into his spiritual and cultural well-being.

Many years ago Sir Alfred Ewing formulated a theory of magnetism which still helps us to understand what happens when a bar of steel is magnetised by an electric current flowing in a coil wound around the bar. Ewing pictured the myriads of molecules in the bar as infinitesimal magnets, each with a north and south pole, but arranged higgledy-piggledy, with the north pole of one molecule attracted to the south pole of an adjacent molecule, when the bar was in the unmagnetised state. In other words, the countless numbers of molecules formed closed magnetic circuits amongst themselves, and there was no resultant magnetic force radiating from the poles. But just so soon as the energising effect of an electric current acted on the bar, this disorderly molecular condition of quiescence was instantly changed. The millions of magnetic molecules aligned themselves in orderly procession as a molecular team objectively controlled, all the north magnetic poles pointing to one end of the bar and all the south poles to the other end. In consequence, the bar now became a strong magnet, its poles exhibited definite magnetic power, and it could be used in diverse ways to render magnetic service.

I give you this picture of what happens in the domain of electro-magnetism because it affords a rather beautiful analogy to the way in which enlightened industrial leadership can energise a group of workers and so convert their quiescent condition into one of dynamic team power and service (see Fig. 4). The human team within an industrial organisation—each member possessing a distinctive personality and definite powers of service—can be likened to the molecular team of which the bar of steel in our analogy is made. The coil of wire wound around the bar could be likened to the higher managerial control which becomes an energising and directive force, through its power of leadership—that intangible influence which truly corresponds to the mysterious and potent force wielded by the invisible electric current energising the coil. Clearly this figment of the imagination can be equally well applied to the associated working of a large group of industrial organisations such as we have in an industry; or to the co-ordination of the wide range of industries within a nation.

3—The Function of Industrial Leadership

The function of industrial leadership is allied to, and dependent on, the function of industry. I have already stressed the view that the main purpose of industry is to improve its service function. Moving from the general to the particular, this conception means that the team of workers within an industrial


Unenergised Condition.
(Molecular magnets working higgledy-piggledy & uncontrolled)
MAGNETISING COIL analogous to MANAGERIAL CONTROL.
Magnetic field (or service) radiating from energised mass.
Energised Condition.
(Molecular magnets working as a Team and objectively controlled)
S
N
ELECTRIC CURRENT IN MAGNETISING COIL analogous to POWER OF LEADERSHIP energising MANAGERIAL CONTROL.

Electro-Magnetic Analogy to the Power of Leadership.

FIG. 4

organisation should be striving continually to improve the service which the products of the organisation give to the team of customers. In other words, "service to customers" will be the main inspiration of the team effort, and enlightened industrial leadership will never cease to embody this vitalising objective in all its plans, programmes, and policies.

In my experience, the foundation for substantial progress is laid once all sections of an organisation are permeated with an attitude of mind which elevates the customer to a position of dominating importance. Whilst we know that the customer is not always right, the *mentality* which *assumes he is right* until an impartial and unbiased investigation of all the circumstances of the case may prove him to be in error, should be wisely encouraged. This attitude of mind, wisely directed and controlled by industrial leadership, will do much to dispel sectional interests and prejudices, by substituting for these disturbing forces a *team interest* in a vital, common, and impersonal objective—the *customer*. Furthermore, in such a mental atmosphere the stimulating and vitalising influence that can come from a customer is allowed to flow freely into the organisation, thereby stifling, by its inductive effect, the greatest enemy of healthy progress—*complacency*.

4—The Main Components of Industrial Service

Now this service which an organisation renders to its customers depends on three fundamental factors—quality, price, and timing. They represent the main components of industrial service, and must ever be uppermost in the minds of the industrial team responsible for their steady improvement. Industrial leadership should use its great powers to focus the outlook and vision of the team on to these primary essentials, and thereby cause a steady acceleration of the service flow in the industrial circuit which it controls, to benefit all the team members, from the highest to the lowest. And in accomplishing this, leadership will find that it is necessary to create, by a process of education, three team senses—a "quality-sense"; a "money-sense"; and a "time-sense". These considerations are of such tremendous importance to those within industry and without that it is desirable to analyse at some length the implications arising from them.

(*a*) *The Quality of the Product*—The quality of the product is the foundation stone upon which the superstructure, representing price and timing, can be erected, in building an organisation dedicated to industrial service. This quality factor is made up of three main components—

(i) The efficiency of the design.

(ii) The quality of the materials used in its construction or fabrication.

(iii) The quality and accuracy of the workmanship applied to these materials in changing their shape and then combining them in accordance with the co-ordinated plan embraced by the design. Craftsmanship has an important influence on this component of quality; and above all there must be considered that intangible team sense of responsibility which is only truly satisfied in knowing and feeling that a superlative result has been accomplished.

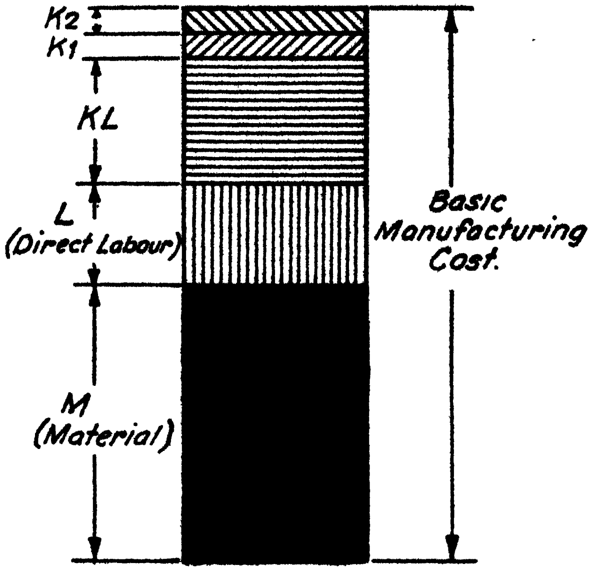
(*b*) *The Price of the Product*—The price of the product is controlled by the basic manufacturing cost—ever an important consideration—and the efficiency of the distributing machine. Reverting to the analysis of the rate of service flow in an industrial circuit already given, it is easy to understand that (r_1+r_2) influence the manufacturing cost, whilst (r_3) is a measure of the efficiency of distribution. The objective all the time should be to reduce the total resistance $(r_1+r_2+r_3)$ to an absolute minimum. Enlightened industrial leadership will recognise this by striving incessantly to improve the quality factor, in association with a reduction both in the manufacturing cost and the ratio between the selling price and this cost; this demands a constant effort to simplify and standardise. And it will determine to secure these results by a steady elevation of human values in all parts of the industrial circuit coming under its control.

It can be stated that—

$$\text{Basic manufacturing cost} = M + (K+1)L + K_1 + K_2$$

Where M $=$ Value of the materials used in course of manufacture.
L $=$ Value of *direct labour* applied to these materials.
K $=$ Value of establishment or overhead charge.
K_1 = Value of wastage.
K_2 = Cost of engineering, draughting, and research.

The chart shown in Fig. 5 should make this clear.



$$\text{Basic Manufacturing Cost} = M + (K+1)L + K_1 + K_2.$$

M = Value of Materials.
L = Value of Direct Labour.
K = Overhead Charge = $\dfrac{\text{Manufacturing Expense}}{\text{Direct Labour}}$
K_1 = Value of Wastage.
K_2 = Value of Engineering, Draughting & Research.

Chart showing make-up of Manufacturing Cost.

FIG. 5

The important factor K is the ratio between the total manufacturing expense and the direct labour in a given period of time. The manufacturing expense is the cost of operating a unit of production, apart from the expenditure of direct labour, and neglecting the sales and distribution costs. In the electrical industry, approximately 60% of the manufacturing expense is incurred as indirect labour—that is, wages paid to superintendents, foreman, chargehands, inspectors, labourers, cranemen, wiremen, millwrights, etc. The value of K may vary over a wide range—from 2·5 to 1·0—depending on the type of product being manufactured. It naturally varies with the productive load, but in general we can state—

$$\text{Manufacturing expense} = KL = K_3 + K_4L$$

$$\text{or, } K = \frac{K_3}{L} + K_4$$

Where, K_3 = Fixed charges such as depreciation, rent, rates and taxes, which are independent of L.

K = A constant dependent on the type of manufacturing unit.

It is true of the electrical industry that over a wide range of products the value of M (that is, money paid by a unit of production to outside suppliers of raw materials) is almost exactly 50% of the manufacturing cost.

Now when we come to consider the increment which has to be added to the basic manufacturing cost—that is the cost of the serviceable product up to the point where it is waiting in the warehouse ready to be moved to the ultimate customer—a somewhat curious state of affairs arises as depicted in Fig. 6. It is unfortunately true under present conditions that with many types of capital goods requiring superlative technical skill both in design and manufacture, the selling price is actually less than the manufacturing cost as shown by diagram (*a*). A healthy condition is portrayed in diagram (*b*). For a wide range of products, generally classed as consumers' goods, we now have the conditions exhibited by diagrams (*c*), (*d*), (*e*), and (*f*). In such cases the ratio $\frac{\text{selling price}}{\text{manufacturing cost}}$ may vary from 1·5 to as high as 5·0, depending on the type of commodity and its service function. Such high ratios are brought about by abnormal resistance (r_3) in the distribution circuit.

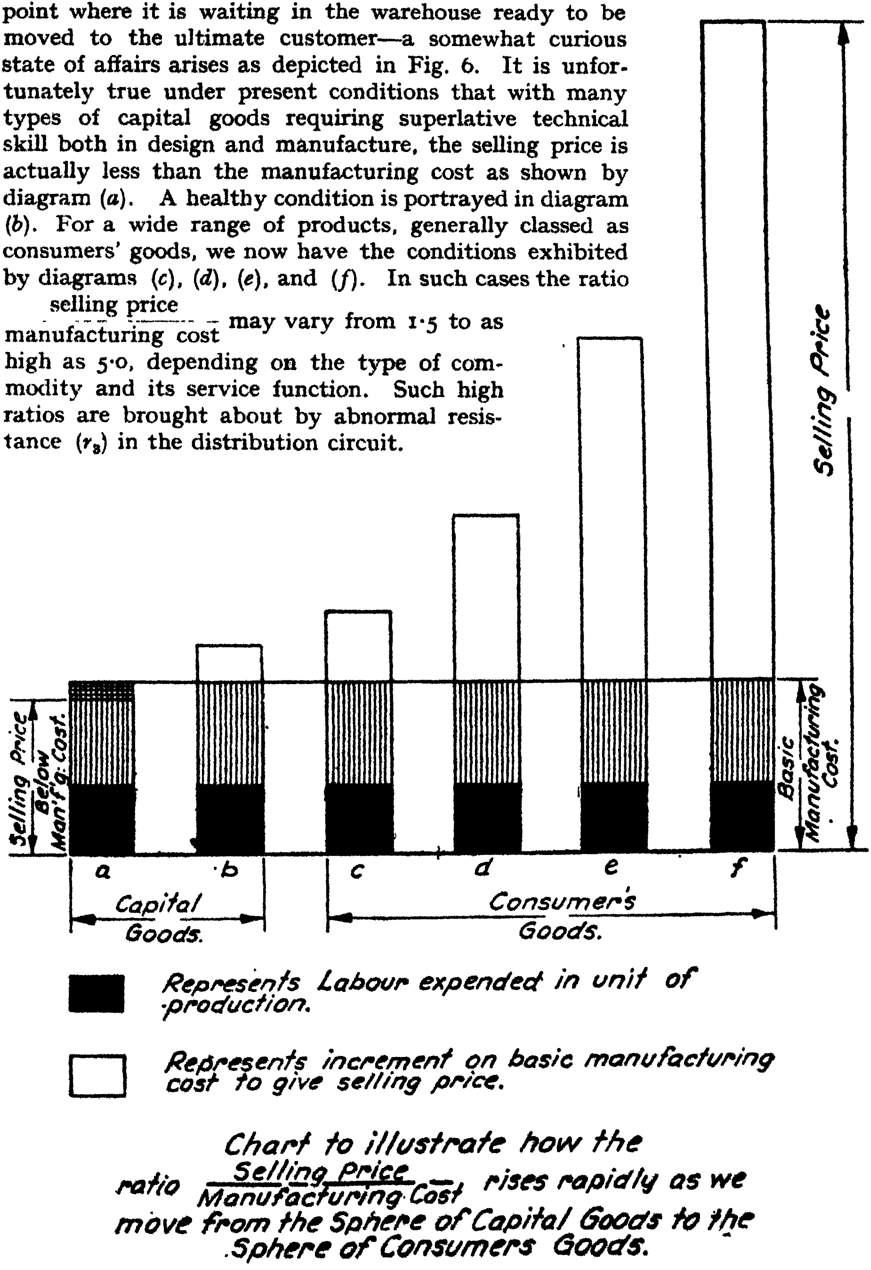


FIG. 6

I refer to this vitally important question at this stage because it is clear that industrial leadership must in the immediate future give concentrated attention to the problem of reducing the distribution resistance (r_3). The growth of marketing schemes is symptomatic of this trend. The root cause of the trouble is that during the past two decades, when the efficiency of our methods of production have been improved beyond all recognition, there has not been the same advance in the technique of distribution. This lag in the application of scientific methods to improve the distribution mechanism is about to be adjusted. But a satisfactory solution of the problem can only be found by the effective co-ordination of production and distribution, so that the complete industrial effort can be unified in the interests of the customer.

(*c*) *The Timing of the Product*—Finally, we must consider the third component of industrial service which I have called "timing". This recognises the growing importance of the "time-factor" in this second industrial revolution when the complex processes of thought and action are being constantly accelerated. A customer not only requires a high quality article at the right price, but he must receive it at the right time if his wants are to be completely satisfied. This consideration has for long been sadly neglected in all industries, but there has been a change of viewpoint in recent years, and industry is moving towards a state when the "timing requirements" of a customer will be viewed in proper relationship to those other elements, quality and price.

The whole question is one of vital importance to industry now that the delivery times associated with new business are getting shorter and shorter. This is but a reflection of that general "speeding-up" process referred to earlier in this lecture. Industry can only meet these increasingly difficult conditions by planning the production flow throughout the three main stages in the industrial circuit—the inflow to the unit of production; the production flow within this unit; and the outflow through the distribution mechanism to a customer. And the total time-cycle embraced by these interconnected processes must be in conformity with the specified requirements of some particular customer. Planning production flow is an immense subject in itself and can only be touched upon here. It involves a scheme of time charting in association with a system of budgetary control if the best results are to be secured. By such means leadership is able to steer the industrial ship along a predetermined course at the right speed.

5—The Qualities of Industrial Leadership

Industrial leadership is made effective through management, which has now become the hub of the industrial wheel. In this simple analogy the spokes of the wheel correspond to labour, whether by hand or brain; the rim to capital; and the track on which the wheel smoothly runs, to the customers. We thus see in proper relationship the four industrial partners, neither one of which is in a dominating position, but all necessary members of the combined industrial team which through a planned effort can secure successful results. Ownership—in the form of capital—is now widely spread. Except in rare cases it is quite impersonal and has no direct human contacts with the industrial undertaking. It should no longer have special privileges, but rather respond to its grave responsibilities by relying entirely on enlightened leadership, in the form of efficient management, to direct the progress of the undertaking along a path of planned industrial service.

You may well ask, what are the qualities demanded of a manager called upon to carry such high responsibility in industry ? I would set them down as follows, arranging them in the order of their importance—

(*a*) Power of leadership as measured by his ability to foster teamwork and direct it towards an enlightened goal of achievement.
(*b*) Creative imagination.
(*c*) Intellectual sincerity and moral courage.
(*d*) Power to co-operate with others.
(*e*) Knowledge of administrative principles.

(*f*) Capacity for delegating authority.
(*g*) Scientific and technical knowledge.

There are many other essential characteristics for the most part embraced by "power of leadership" which naturally heads the list, such as—

(*a*) Reliability.
(*b*) Knowledge of the personal characteristics of his associates.
(*c*) Willingness to receive suggestions.
(*d*) Ability to criticise without antagonising.
(*e*) Ability to make just decisions at all times.
(*f*) The possession of a character and personality which is unanimously respected for its justness and honesty of purpose—but not necessarily liked.

The manager's chief duty is to engender, by teamwork, a group power rather than express a personal one. In all his fundamental thinking he will visualise the activity of the team. and so formulate his plans and policies that the team effort will be utilised to secure the objective in view. His link with the team will ever be very human but impersonal, and he will continually stress the view that the results secured come from the team effort and not because of any direct or indirect influence he may have had on this effort. This demands a high degree of unselfishness and humility—perhaps the greatest of virtues—but it is an essential condition if the power of the team is to be expanded. *Because this expansion will only come if every member of the team is made to feel that he has made a real contribution to the visible results which have come from the co-operative effort of the team.* The late Mary P. Follett, who had very enlightened views on industrial leadership, well expressed this conception of the power of the team or group when she said—

> "We get power through effective relations. This means that some people are beginning to conceive of the leader not as the man in the group who is able to assert his individual will and get others to follow him, but as the one who knows how to relate these different wills so that they will have a driving force."

In brief, successful management means the objective control of human thinking and action along a planned path of industrial service. The manager of the future has got to be a teacher, a preacher, and in large degree he must possess the intangible qualities of the artist. He must also be an educationalist, and in this capacity he will encourage the wise development of apprentice training schemes, recognising fully that the future growth of the organisation controlled by him is fundamentally dependent on the action taken to expand and strengthen the human structure. Silently and alone in that valley of loneliness inseparable from true leadership, he will wield his power, not in any obvious or fussy fashion, but imperceptibly and intangibly in the spirit of the truth that "Whosoever would become *great* among you shall be your *servant*, and whosoever would be *first* among you shall be the *bond servant* of all".

No problem is of greater importance to industry than that of training and directing the stream of young human material flowing into it from our educational institutions, so that future industrial leaders can thus be created who will do the job of work better than those now occupying the high positions in industry. There is a science as well as an art of management. Education for management is one of our greatest national needs. The status and dignity of the managerial function must be elevated, and it is a happy sign that recently there has been formed a confederation of associations concerned with different phases of management, such as buying, producing, and selling. Those interested in this movement feel that this effort at rationalisation within the field of managerial technique may soon result in the creation of a British Management Institute now long overdue.

Enlightened management will ever view the human structure of industry as an organic growth; as a living and soulful thing vitalised by the aspiration and desire welling up for serviceable expression in every human unit. Those entering the various stratas of directive responsibility must be carefully chosen, but there must be free opportunity afforded to every human unit to move from a lower stratum to a higher, as his powers of service grow, and the highest position of leadership should be open to each and every member of the team. In a sentence, the organisation must be democratic to the core, the growth possible to any member being dependent only on his personal characteristics and ability as a human unit to wield successfully greater and greater responsibility.

6—The Education and Training of Supervisors

I am now touching on a problem of vital importance to the whole future of industry. Industrial leadership must give it primary attention, because it is not only concerned with the training and evolution of future managers, but also with the provision of that much larger team of executives needed to direct and control industrial effort in conformity with the higher managerial policy—I refer specifically to assistant managers, superintendents, foremen, assistant foremen, chargehands, and the like. Because we must never forget that the "atmosphere" in which the great body of workers perform their allotted tasks; the spirit of their endeavour; the degree of happiness reached in their daily toil, and their mental picture of the "worth" of the firm which employs them—all these vital reactions are determined, very largely, by the functional ability of that stratum of control composed of a team of foremen or supervisors.

An enlightened managerial policy will continually direct its attention to the question of securing the right kind of industrial atmosphere, in which the whole team of workers will be able to give maximum service. Clearly, under such conditions the individual foreman's task should become easier, but on the other hand it always remains the function of management to see that the foreman and other departmental heads are radiating an atmosphere in the particular sections coming under their control, which is of the same quality and texture as that which the higher managerial control desires to see permeating the whole organisation.

This is a vital consideration. A single foreman controlling perhaps a very small proportion of the total number of workers within an organisation can, through lack of leadership, inability to interpret the managerial policy, and failure to give the workers under his control a square deal, do incalculable harm to the whole human structure. The evil forces spread out from the small section where the inefficient foreman is failing in his duty. If the higher managerial control is not extraordinarily alert, these forces can gradually poison the team spirit of the organisation—that intangible factor of dominating importance.

If I had to set down in order of importance those characteristics which a foreman or supervisor should posses, I would give them as follows—

(*a*) Power of leadership.
(*b*) Reliability.
(*c*) Initiative.
(*d*) Tact.
(*e*) Technical and manipulative skill.

In other words, he must first be a leader of men and able to secure results through effective teamwork. Mr. L. Urwick very rightly says in his excellent book "Management of To-morrow" recently published, when discussing this question—

> "Leadership and Co-operation. These are the two—and the only two—ends of of importance towards which systems of Foremen's education should be directed."

He then goes on to say—

> "Co-operation is a state of mind. Men can be taught to co-operate on one basis and one basis only; enthusiasm for a common object which they understand and appreciate."

Clearly the problem of training foremen or supervisors is extraordinarily difficult, because the necessary qualities of which I speak are more closely allied to matters of the spirit than to intellectual ability. The educational training which has been given to those entering industry in the past has had far too strong a technical bias. Forces are now at work which, in combination, should bring about a gradual change, but until this happens we shall not be in sight of an adequate supply of men having the qualities prescribed, for filling these positions in industry. Dr. J. A. Bowie in his enlightened book "Education for Business Management" says—

> "Technical executives, as a class, tend to concentrate on routine problems, the side of good management that has to do with plant, equipment, and quality of product, and they are prone to neglect the inexact "art" of handling human beings for the sake of problems more intellectually fascinating to them. In other words, a narrow technical training, limited to the quantitative sciences, does not fit a man to assume the leadership of men."

And then, in another illuminating passage he says—

> "A workshop is as full of feelings as it is of machines, and no man whose training has left him with a dislike for, and inability to deal with, the imponderables of ethical and psychological considerations is qualified to assume control."

This great question which must be solved by industrial leadership if industry is to progress in the right direction, is fundamentally one of education. And because this is so, the roots of the problem run deep. Whilst industry can do much, and much more than is now being done—especially in our older basic industries such as coal, textiles, shipbuilding and steel—to find a solution, it is clear that ultimate success can only be realised by the wise and purposeful co-operation of industry and education. The responsibility for evolving a satisfactory process of training and selection must be shared by both, with the common aim of giving communal and national service.

Industry has suffered in the past, and still suffers, from the erection of an artificial barrier between the preliminary educational stage and the subsequent and more prolonged, industrial educational stage. These barriers must be broken down, and the complete cycle of education viewed in unified and broad perspective. Progressive educational thought is moving in this direction. Lord Eustace Percy, a late Minister of Education, has said—

> "We have to inform industry of the structure of education as it exists, indicating the reform we are endeavouring to carry out and the objects we are seeking to attain· and we have to devise *new* machinery for working out plans for further development in harmony with the requirements of trade and industry."

I desire to stress the paramount need of the common alignment of the forces operating within our educational and industrial institutions, because this need permeates the very core of the problem now under review. Industry and education no longer connote two separate worlds of human thought and action. The rapid and continuous changes in industry are having an inductive effect of tremendous importance on education. Our educational methods must respond to this influence, so that the national team can move forward along a more enlightened plane of endeavour and achievement.

To illustrate this line of thought, just visualise a future industrial state when the material plane of existence has been greatly elevated with an enormous reduction in the hours of daily toil—say to 20 hours per week. This is no wild visionary forecast but a practical achievement which must inevitably come from the steady development of the scientific mind. But do our educationalists realise fully that this tremendous change may mean that within two generations our whole educational objective will have to be swung through half a circle, and the system so modified that education in the preliminary and all important stage, is for leisure and not for labour ?

SECTION 5—WHITHER INDUSTRIAL LEADERSHIP ? WITH SPECIAL REFERENCE TO THE TEXTILE INDUSTRY

Industrial leadership will, in the future, only be effective in so far as it successfully combines two primary impulses—the making of things and the making of men. The organic and dynamic structure which it controls must not only produce in growing abundance serviceable goods of the right quality, sold at the right price, and delivered at the right time, but the performance of this function must be accompanied by the development of better and still better men, within industry and without. The realisation of this great truth is already bringing about a

rebuilding of the whole national industrial machine. We are all part of this machine, and in greater or lesser degree responsible for the task of reconstruction now facing us. You may well ask, what kind of plan should industrial leadership keep before the industrial team as it directs the work of rebuilding just beginning.

1—Industry Strives to Plan

I stated earlier in this lecture that "planned co-operation" must be the guiding principle in the future. It is obvious that the basic idea of planning production flow within a unit of production can always, within limits, improve the efficiency of that unit. But it is abundantly clear that the optimum benefit can only accrue when similar and co-ordinated action is taken in the tens of thousands of other units, both large and small, which go to make up the nation's industry.

The importance of planning industrial action is beginning to be appreciated in this country by those within industry and without. We have already begun to travel this industrial path as exemplified by the B.B.C., the C.E.B., the London Transport Board, and more recently the Milk Marketing Board. But we have yet to travel a long way before a National Planning Control mechanism for maintaining the National Industrial Generator in proper balance, is within sight of achievement. It is good, however, that a beginning has been made, and I venture the prediction that the pressure of economic events in this and other countries—notably U.S.A., Russia, Germany, and Italy—will accelerate the movement we must inevitably make along this path leading to a more enlightened and balanced industrial future

The proper application of this simple and commonsense idea—and all great ideas are fundamentally of simple origin—can bring untold good to the nation. But the magnitude of the communal benefits which should result will depend on four important things.

1—The degree to which the human unit is trained to develop his thinking and action along a planned path, having service and not self as its ultimate goal.

2—The degree to which the human unit is educated to the conception that "individualism", connoting as it does freedom of thought and conscience, must be applied in a spirit of co-operation to the common good—"We are all members, one of another".

3—The degree to which a group of workers concerned with a common industrial purpose can be made to work together as a team, towards the goal of expanding the service which comes from their united effort. The team spirit—the intangible factor which more than any other controls this result—will inevitably depend on (1) and (2).

4—The degree to which teams of workers concerned with a common industrial purpose can be made to co-operate as a complete national team for the purpose of expanding the service function of the industry of which they form the constituent and all important human parts.

Education must play a great part in solving the human and psychological problems suggested in (1) and (2). But the change in mental outlook which I have thus indicated is beginning to fructify, and great impetus could be given to the movement by enlightened leadership from above.

2—An Industrial Parliament Visualised

In my book* published towards the middle of 1933, I took as my main theme "Plan to Serve". I tried to show how the application of this principle to individual and collective industrial effort must logically lead to the final creation of an industrial Parliament. I visualised 12 basic industries—one of which was textiles—each made up of numerous industrial units, but all aligned in respect of their common service function. Each of these industries would be co-ordinated and controlled by a Planning Control Board, democratically elected by the industry, to represent in balanced proportion the four industrial partners portrayed in my earlier analogy of the industrial wheel (see Fig. 7). Each Planning Control Board would be served by a permanent executive team of functional experts, to do the work of co-ordination in conformity with the over-ruling policy and direction of the Board. The Board would be elected for a period of five years, so that its composition could be changed at the end of this period if the industry so desired. In this scheme of control, production and distribution would be linked together as one industrial problem. An Industrial Planning Control Board would, in effect, control all the forces operating within the complete productive cycle as embraced by my conception of an industrial circuit.

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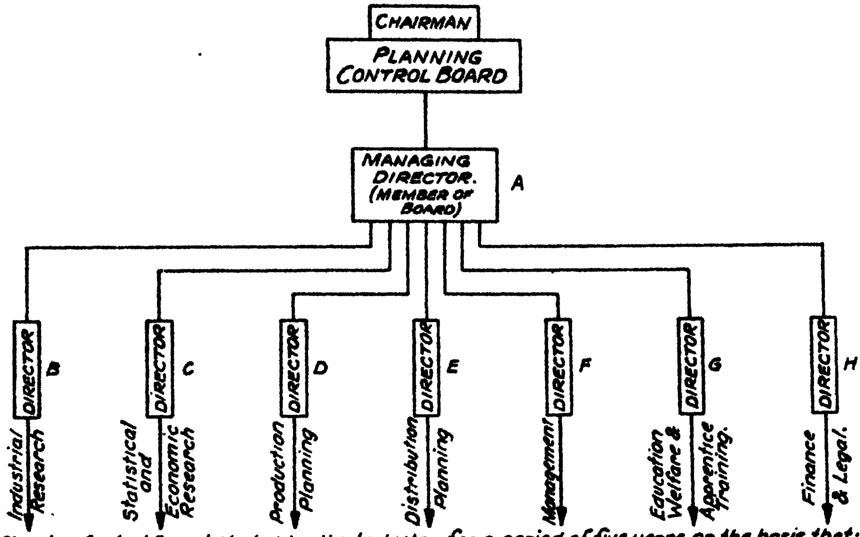
* "Forward from Chaos," by A. P. Young, O.B.E.
See also "Reconstruction", by Harold Macmillan, M.P.



Planning Control Board elected by the Industry for a period of five years on the basis that:-
6 Members represent Labour
6 Members represent Management.
6 Members represent Capital.
6 Members represent Customers.
A, B, C, D, E, F, G & H are the leading functional members of a permanent executive team, controlled by the Board and therefore by the Industry.

COMPOSITION OF PLANNING CONTROL BOARD FOR AN INDUSTRY CONCERNED WITH A PARTICULAR SERVICE.

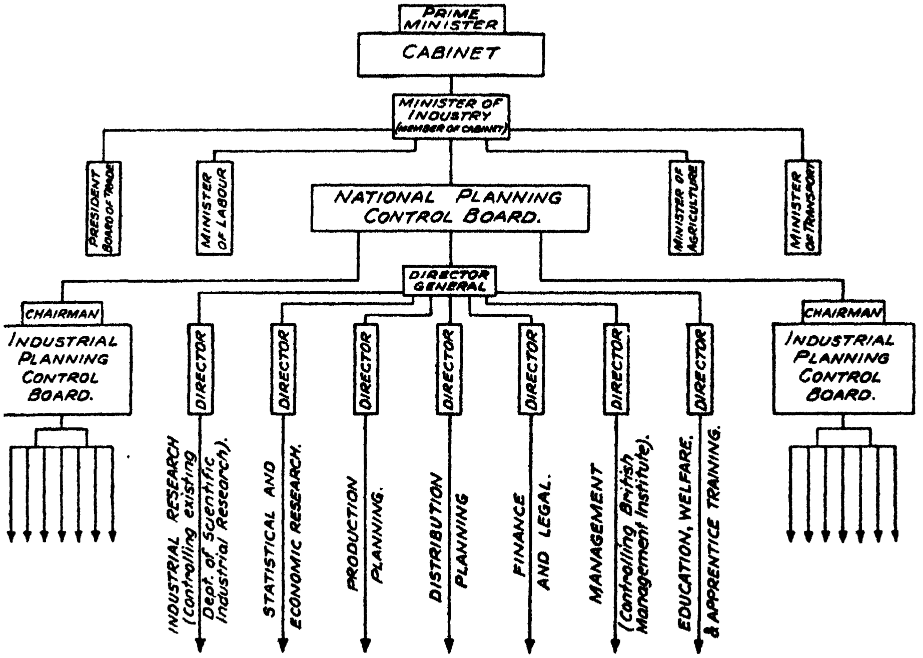
FIG. 7

There would be, in addition, a National Planning Control Board comprising the 12 chairmen of the Industrial Planning Control Boards; the heads of certain government departments now concerned directly with industrial functions; and three independent members elected by the Prime Minister of the day—a total of 25 members including a chairman, who would be a Minister of Industry with a seat in the political cabinet (see Fig. 8). Thus there would be an Industrial Parliament of 288 members, and an Industrial Cabinet of 25 members. The chairman of the latter, by being a Minister of Industry, would form a simple but effective link between the existing political control mechanism, and the new industrial self-governing control mechanism that is visualised.

3—Leadership and the Textile Industry

In concluding this lecture it is appropriate that I seek to determine how those principles of leadership which I have sought to establish, might be applied to the inner working and higher control of the textile industry. I approach this problem with diffidence, but with sympathy, and in a spirit of optimism so necessary to purify the deadly atmosphere created by prolonged pessimism and despair. The position at the moment is that the great textile industry of this country employs just over 1,000,000 insured workers. Roughly 400,000 of these are in the cotton trades, and 200,000 in the woollen and worsted trades. The unemployed register carries roughly 200,000 insured workers, and almost exactly one half of these are in the cotton trades.

It was inevitable that the steady deceleration of world trade which characterised the economic cataclysm of 1929–1933 should have dislocated an industry which had been built up mainly on its export trade. In 1929 the cotton and woollen industries, which absorb about 60% of the workers in the whole textile industry, exported £187,000,000 worth of goods representing no less than 26% of the total export trade of this country. By 1932, our export trade had been reduced to almost exactly one half the 1929 figure and the cotton and woollen industries had lost £100,000,000 worth of business.


PRIME MINISTER
CABINET
MINISTER OF INDUSTRY (MEMBER OF CABINET)
PRESIDENT BOARD OF TRADE
MINISTER OF LABOUR
NATIONAL PLANNING CONTROL BOARD.
MINISTER OF AGRICULTURE
MINISTER OF TRANSPORT
DIRECTOR GENERAL
CHAIRMAN
INDUSTRIAL PLANNING CONTROL BOARD.
DIRECTOR
DIRECTOR
DIRECTOR
DIRECTOR
DIRECTOR
DIRECTOR
DIRECTOR
CHAIRMAN
INDUSTRIAL PLANNING CONTROL BOARD.
INDUSTRIAL RESEARCH (Controlling existing Dept. of Scientific Industrial Research).
STATISTICAL AND ECONOMIC RESEARCH.
PRODUCTION PLANNING.
DISTRIBUTION PLANNING
FINANCE AND LEGAL.
MANAGEMENT (Controlling British Management Institute).
EDUCATION, WELFARE, & APPRENTICE TRAINING.

COMPOSITION & RESPONSIBILITY OF NATIONAL PLANNING BOARD.

FIG. 8

There has been some recovery during the past 12 months as shown by the unemployment figures. At the end of last March the total unemployed insured persons in the cotton and woollen industries stood at 132,000, representing a reduction of 41,000 on the corresponding figures for the end of March 1933. This improvement was proportionately greater in the case of woollens than with cotton. Because of the magnitude of the cotton industry in relation to the whole textile industry, and the distressing nature of the economic and psychological forces which are operating to prevent a quick recovery, it has long been recognised that the core of the textile problem is in the cotton trade. In actual fact the jute industry is relatively worse off and is faced with a similar problem but of lesser national magnitude owing to the smaller size of this industry. At the moment approximately 25,000 insured workers are employed in the jute industry, which at the end of last March had an unemployed percentage figure of 28·1 as compared with 21·1 for cottons.

(*a*) *The Cotton Industry*—Now what are the forces which are preventing recovery in the great cotton industry? They can be simply stated thus—

(i) *External*—Loss of export markets, notably in India, brought about by the establishment of mills there to manufacture the cloth previously bought from Lancashire. It should be noted that this is the logical outcome of that spirit of intense nationalism which has been abroad throughout the world since the war. The situation has been aggravated by the rapid growth of Japanese competition in recent years, and the depreciation of silver currency.

It is estimated* that Indian and Japanese production has each increased by about 1,300,000,000 yards of cloth since the war, and that in consequence of this, Lancashire has permanently lost this market for nearly 3,000,000,000 yards of cloth. The present manufacturing equipment in Lancashire embraces 54,000,000 spindles and 680,000 looms; and it is estimated that 8,000,000,000 yards of cloth must be sold in the home and export markets to keep this equipment fully employed. Approximately one-third of this equipment has become redundant unless new markets can be created, either at home or abroad, to make good this enormous loss.

(ii) *Internal*—Failure to grapple courageously with the internal problem of reorganising, revitalising, and realigning the industry to deal with the rapidly changing world conditions. This central problem still remains and can only be solved by enlightened leadership. It demands a new attitude of mind which in the great majority amounts to a mental revolution; a spirit of co-operation; a co-operative plan based on an *unshatterable faith* in the future great destiny of the industry; new leaders with a scientific outlook, some of whom might well be drawn from our younger industries; and the clarion call of exalted leadership to make the plan real and effective.

(*b*) *A Cotton Planning Control Board*—The three golden keys unlocking the door to balanced progress in the cotton industry, or indeed in any other industry are—planning, teamwork, and service. And an enlightened management factor, operating on the principles already enunciated, affords the means by which these keys can be used to some good purpose. Once the door is opened, and the inner desire created for co-operative effort objectively controlled, it becomes possible to construct a planning control mechanism for governing the activity of the whole industry with its multiplicity of sections and sub-divisions, so that it may steadily improve its service function. I am impressed with the plan for a control board put forward by the Trade Union Congress in November 1933, which is strikingly similar to the type of Industrial Planning Control Board already discussed. The scheme is based on sound fundamental thinking, so much so, that I venture to predict that some such plan of higher control for the whole industry will eventually be adopted. There is no other adequate solution of the tremendous problem now confronting the industry, but a greater spirit of co-operative effort must first be engendered before any plan of this kind can be made to work.

One of the great difficulties arises from the fact that the industry is old in body, and having grown through the whole period of the first industrial revolution it is still encumbered with wasteful growths and bad traditional thinking which are not found in some of our newer industries. And being old in body there is danger of the mental machine failing unless drastic action is taken to rejuvenate the human structure of the industry by infusing new blood into it. The industry must rediscover its soul.

Wise industrial leadership would first create an atmosphere favourable to balanced and healthy progress by inducing a mental outlook which is directed away from the wonders of the past and the demoralising conditions of the present, to the *illimitable opportunities which lie ahead.* It would then focus attention on the great and common objective of the industry—co-operative service to the ultimate customer in the form of the highest quality cotton cloth, sold at the lowest possible price and made available in the quickest time. On this mental and spiritual foundation it would, in my judgment, be relatively easy to erect the type of planning control mechanism which I have in mind, for giving self-government to the unified and co-ordinated industry, on the basic principle that management, labour, capital and customers would be equitably represented on this higher control board. Unless such action is taken quickly by the industry itself, of its own volition, it is inevitable that Government pressure will ultimately force through a reconstruction plan, because it cannot for ever allow such a powerful industry to flounder in the trough of inefficiency and despair.*

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* See article "Present and Future of the Cotton Trade", by S. S. Hammersley, M.P., *Manchester Guardian Commercial*, 13th August, 1932.

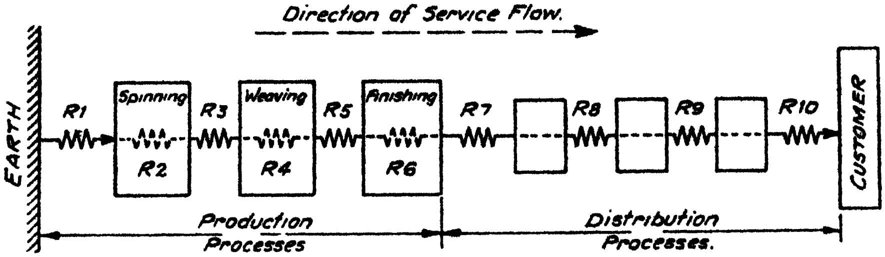

Chart showing production flow in Industrial Circuit of the Cotton Industry.

FIG. 9

Just glance at Fig. 9, which shows by means of a simple diagram the course of the service flow in this industry, from mother earth to ultimate customer. There are broadly three production processes—spinning, weaving, and finishing. Each of these is an enormous industry in itself, permeated with bad traditions, unscientific thinking, selfishness, jealousy, class distinction, and lack of faith in its power and purpose as a unit of industrial service. Running through the complete industrial circuit there is too little appreciation of the dominating influence of the human factor, and too frequently there is to be found that disturbing element which always arises when the function of ownership is confused with the function of management. And nothing like enough attention and encouragement is given to research—upon which the future well-being of every industry is so vitally dependent. Lastly, there is no adequate provision in the form of well-conceived apprentice training schemes for attracting into the industry from our schools, technical colleges and universities a steadily expanding stream of young human material such as we find in some of our newer industries—notably the electrical industry.

The integration of these bad influences manifests itself as *resistance* at all points in the circuit shown in Fig. 9. I have shown *ten* resistances to illustrate this argument, each of which is capable of reduction, through improved organisation, methods, and processes. They can be divided into three main groups as follows—

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*The report presented to Parliament in July 1930 by the Committee on the cotton industry says—

"We are confident that the organised operatives and employees of Lancashire will embark forthwith upon the serious consideration of the measures essential to the recovery of their trade. If, however, this hope is disappointed, or if any section proves recalcitrant, we think it right to place on record our considered view that it would be the duty of His Majesty's Government themselves to consider inviting Parliament to confer upon them any necessary powers."

1—($R_1+R_3+R_5$)—Resistances interposed in the productive part of the circuit, external to the producing units. R_1 is related to the flow of raw cotton from U.S.A., Egypt, Australia, and other cotton-growing countries to the spinning mills in Lancashire. This resistance can be reduced by using successfully cheaper raw cotton, such as the short-stapled Indian cotton, used extensively by the competitors of Lancashire in supplying cheap standard lines to the Eastern markets. The great possibility of expanding the growth of cotton within the Empire, which work is being fostered by the British Cotton Growing Association, has direct bearing on this problem.

R_3 and R_5 relate to the passage of the spun thread to the weaving sheds and from thence to the finishing mills. These parts of the circuit should be as short and direct as possible. Everything should be done to reduce (R_3 + R_5), because any wasteful increase in either simply inflates the ultimate selling price and retards the rate of flow in the complete circuit.

2—($R_2+R_4+R_6$)—Represents the total resistance in the series of productive units through which the cotton has to pass before it is transformed into cloth capable of rendering a specific service. The problem of reducing this total resistance is primarily one of management. The development of a team spirit; the scrapping of obsolete plant and equipment, and its replacement by modern automatic or semi-automatic machinery,* a big forward move' in the direction of electrical mechanisation; the introduction of scientific methods of planning and controlling the production flow; an impetus given to research objective to improving the product and reducing the cost in association with an improved wage level—all these forces would be blended by efficient management to secure a steady reduction in this total resistance. The formation of a Producers' Association to co-ordinate and align all the processes from raw cotton to finished cloth, could open the way for a revolutionary improvement.

3—($R_7+R_8+R_9+R_{10}$) are concerned with the grave problem of distribution and marketing. Viewing the problem as I do from some distance, it is obvious that this part of the circuit, linking as it does the production unit responsible for the finished article with the ultimate customer, needs to be drastically simplified. There would seem to be a wonderful opportunity for a Marketing Corporation to simplify, co-ordinate, and control the process of distribution.

This picture of the situation brings out one cardinal fact which cannot be overstressed. It is simply this. The team of half-a-million or so people working in the cotton industry—from the Managing Director in his boardroom, right down the serried line to the humblest mill girl—are all concerned with the common problem of producing cotton cloth to give maximum service to the vast multitudes who purchase it. Once the outlook of the team can be elevated to the common and determining objective—maximum service to customers—I feel convinced that an inner urge will develop, impelling the whole industrial team to remove at all costs the present inefficiencies, so that it can with robust confidence face the future, inspired by a glowing faith in its great destiny.

The formation† of a Producers' Association to control all phases of production, and a Marketing Corporation to control all phases of distribution, would pave the way for the creation of a Planning Control Board on the lines already suggested, to direct the future destiny of the industry. Such a Control Board would provide an effective and indispensable link between production and distribution, maintaining a proper co-ordination of effort in the interests of the whole industry and the great community served by it. To this end it would provide self-government for the industry on an enlightened plane, by ever maintaining a just and harmonious balance between those three fundamental factors—wage level, price level, and dividend level.

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* H. T. Tizard, C.B., F.R.S., in his excellent 1929 Mather Lecture, "Science and the New Industrial Revolution", says—

"All the machines used in the textile industries are out of date. None of them has really received the close scientific study and analysis which the provision of scientific instruments to-day permits to be carried out with the greatest accuracy."

† Suggested in a broadsheet issued by P.E.P. for 30th January, 1934, which deals with "Cotton Reconstruction".

(*c*) *The Textile Industry*—The cotton industry is the major unit, but still a unit, in a larger industrial structure—the textile industry—which gives employment to at least one-and-a-quarter-million people. This great industry is fundamentally concerned with producing a multitudinous array of fabrics designed for ministering to our individual and collective needs, as well as for industrial purposes. In performing this service function it uses seven basic fibrous materials—

Cotton
Wool
Flax
Jute
Hemp
Silk
Rayon

To these might be added rubber threads and asbestos—both of which find increasing application in the industrial sphere.

All the production processes in the textile industry are concerned with spinning, weaving, finishing, and colouring these fibres, either as distinctive groups or as a combination of one group of fibres with other groups. The finished fabric is used mainly for clothing; but there are many other applications directed to rendering service in the home. *A relatively new growth with enormous potentialities* is the use of fabric for industrial purposes such as canvases, belting, aeroplane wings, filter cloths, insulating tape, the covering of wires for the electrical industry, tyre cords and moulded gear wheels having noiseless characteristics. In the latter case we are witnessing an invasion of the mineral kingdom by the recurrent products of the vegetable kingdom—cotton cloth treated with synthetic varnish and then moulded at a high temperature under great pressure to give a resultant material which can be used in place of steel, cast-iron, and other non-ferrous metals. True, a small beginning as yet, but what an alluring vision of future possibilities is presented to the mind of the creative worker by this relatively small step along an entirely new path of textile development !

The common aim and purpose running through the complicated network of manufacturing processes in the textile industry is the ultimate production of a fabric which will serve some particular human need. It is this common fabric service objective which provides a basis for aligning and co-ordinating the production and distribution phases of the whole industry in conformity with a scientifically regulated plan of advancement. Clearly, the woollen, jute, linen and rayon industries could become self-governed industrial units, by each creating from within a planning control mechanism on the lines of that suggested for the cotton industry. Once this was done, the next step would be for the self-governed industrial units to establish, in association, a higher control and governing mechanism for the whole industry, in the form of a Textile Planning Control Board. This may strike many of you as a somewhat revolutionary conception, but the steady application of the indisputable principle of planned co-operation on the basis of an aligned service objective must, as I see it, finally lead to the reconstruction of the textile industry on these lines.

Nobody can foretell exactly what the future holds in store. But it can be safely predicted that the *textile industry possesses at this critical moment in its history enormous and untold potentiality for further growth and human service.* Why do I say this ? Because, its service function deals broadly with three groups of human needs, each of which can be made to surpass our wildest dreams once humanity begins to move forward as a world team along a more enlightened and unfettered path of progress. These three main groups are—

(*a*) Adorning and beautifying the human body—clothing.
(*b*) Adorning and beautifying the home.
(*c*) Industrial purposes.

Now during the next 50 years it is certain that the efficiency of industry will be improved to a degree well beyond our present comprehension. The hours of labour will be steadily reduced; the hours of leisure increased and intelligently utilised; and this immense change in the lives of all civilised peoples will be associated with a gradual uplifting of the material plane of existence. These radical changes in our daily lives will produce many reactions, one of which is that all people will give greater attention to their own personal adornment and also to the comfort and artistry of their homes. What boundless opportunities such a vision of the future should present to those of you who are so intimately concerned with the working of the textile industry ! Just visualise a condition when it is possible for every woman to buy a new dress every month, and for a man to purchase just as frequently a new suit of clothes ! ! The output demanded of your industry to deal with such a condition would have to be increased many times and you would then not be inclined to worry about the loss of big markets mainly concerned with low grade fabrics used for clothing many millions who are unfortunately not so well placed as ourselves.

Make no mistake. The present phase of intense nationalism will pass. A new era of internationalism will then unfold itself, and as we advance as a co-operative world team, the material conditions in all countries will steadily improve. The day is past when one country can forge ahead more rapidly than another. The process of unification is spreading to world evolution; and the rate of progress made in a highly industralised country like our own will be influenced and to some extent controlled by the rate of economic advance, say, in India, Japan, and China. As I see it, the progress of the whole world towards a higher material plane of existence, which is the one good thing that must be extracted from this scientific era, will be in stages as portrayed by the charts in Fig. 10.

I refer to this question because I cannot escape the conclusion that this trend which is already manifesting itself, is of deep concern to your industry. It should fill you with immense optimism, and stimulate an inner desire to reconstruct its human and material mechanism, so that this industry can worthily meet the increasing demand which the human race will make upon its service function. There are great psychological forces on your side, because as the material plane on which we humans live is raised, I think there is good ground for believing that an expanding proportion of the national income will be spent on beautifying the person and the home. By the quick translation of right thinking into right action, your industry can attract to itself a large portion of this potential expansion in home purchasing power.

With such a vision of the future ever before you, to encourage and inspire, the work of reconstruction on the general lines indicated should become purposeful and joyful. As I judge the position, one of your immediate tasks is to organise a planned thrust on the evolution of high-grade fabrics, to meet present needs and others yet to be created. Concentration on the high quality market, making and maintaining it at the highest quality level in the world, should be your primary objective. This can be done by utilising to the full, in your industry, that superb scientific, engineering, manufacturing, and marketing skill which this country possesses in abundance. Such a policy would leave the industry free to exploit the distinctive ability and skill of our people, leaving to others who have not these inherent advantages the markets in low grade cloths, which you once held. At first sight this may appear to be a policy of defeatism. But this is not so, because it is well within the bounds of possibility that with improved mass production methods applied under a system of "planned control", the lost markets could be recaptured with a high grade cloth sold at a Ford price; that is, by giving the ultimate customer superlative and unapproachable service.

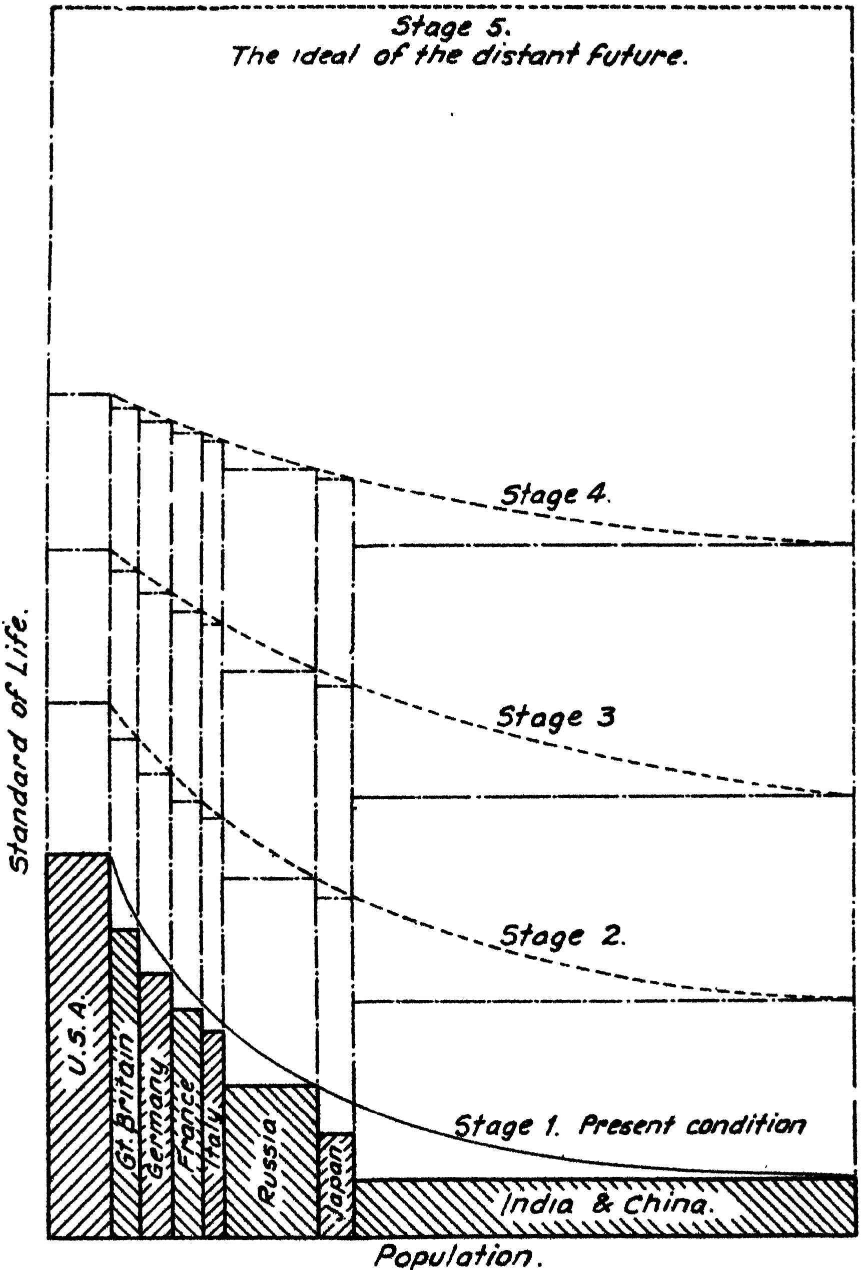

Chart showing how Standard of Life in all countries will move towards unification now that world progress is closely interconnected.

FIG. 10

This brings me to the vital question of research. There are at present five research associations dealing with fabrics.

The British Cotton Industry Research Association.
The Wool Industries Research Association.
The British Silk Research Association.
The Linen Industry Research Association.
The British Launderers' Research Association.

I venture to suggest that the formation of a co-ordinating body to control and unify the activities of these five research associations, so that the research effort is objective all the time to producing a balanced growth in the textile industry, would be of inestimable benefit. I do not know the total sum of money being spent annually in these research associations, but I can say without fear of contradiction that it is not enough. Of course, many of the larger industrial units have their own research departments, but the total expenditure on research throughout the whole textile industry is probably less than one-tenth of 1% of the total turnover of this industry.

The whole of British industry suffers from the paucity of our present rate of expenditure on research. Some industries are in a better position than others, and I would judge that the situation in the textile industry is especially bad. I believe industry has already reached a stage of evolution where the total annual expenditure on research should be at least 1% of the total annual turnover, and in some of our highly efficient and progressive industrial units this condition is fulfilled. There is good ground for stating that only by the pursuance of such a policy can industry maintain the right rate of progress.

Industrial leadership in the textile industry could with great wisdom do four things quickly—

(*a*) Co-ordinate the activity of the five research associations now existing.
(*b*) Stimulate the establishment of industrial research departments within those units of production wherein the "research sense" has not yet developed.
(*c*) Secure close co-operation between the work of the co-ordinated research associations, and the work done in the various industrial research departments.
(*d*) Inaugurate a campaign to encourage and expand the whole research activity of the industry, by planning to increase the present rate of expenditure by at least five times within the next five years. If wisely and purposefully spent—on machines as well as materials—this increased disbursement would be returned to the industry many times over within a relatively short period.

Research work on textile fabrics is concerned with developing new fibres, new processes, new and improved machines, and new and hitherto unimagined fabric applications. The creative and adventurous mind of the research worker is needed to grapple successfully with these complex problems. The task is ever widening, and spreads out into the realms of physics, chemistry, electricity, and engineering. It goes deep down into the very structure of the atom itself. As Dr. R. H. Pickard has said—

> "There is another, very modern, branch of physics now being developed which *may one day be of practical application in the textile world.* I refer to the so far but little used technique of molecular rays."

The research worker, given his head and opportunity to use the growing and prolific store of scientific knowledge and technique ever available to him, may well evolve new synthetic fibres, and combinations of the present known fibres, which will give a sudden impetus to the growth of the textile industry. By this and other means already touched upon, your industry can forge ahead along that certain path of evolution already visualised, with exalted courage and abiding faith in its great destiny to give in growing abundance to humanity that delectable service to which it is dedicated.

BIBLIOGRAPHY

I give below a very limited selection of publications—mostly of recent origin—from that vast and ever expanding store of literature which treats in great detail many of the problems lightly touched upon in my lecture.

The Scientific Era

- "The Scientific Outlook", by Bertrand Russell.
- "Science and the Modern World", by A. N. Whitehead.
- "Science and the New Industrial Revolution", by H. T. Tizard, C.B., F.R.S. The Mather Lecture (1929).
- "Science To-day", planned and arranged by the late Sir J. Arthur Thomson, M.A., LL.D.
- "The Progress of Science", by J. G. Crowther.
- "The Birth of the Future", by Ritchie Calder.

Philosophy and the New Era

- "Mind in the Making", by J. H. Robinson.
- "Adventure of Ideas", by A. N. Whitehead.
- "Process and Reality", by A. N. Whitehead.
- "Essays in Common Sense Philosophy", by C. E. M. Joad.

Christianity and the Crisis

- "Industry and Property", C.O.P.E.C. Commission Report, Vol. IX.
- "Whither ?" by the Rev. the Hon. Edward Lyttelton, D.D.
- "Can Christ Save Society ?" by A. E. Garvie, D.D.
- "A Christian Sociology for To-day", by Maurice B. Reckitt.
- "Christianity and the Crisis", edited by Dr. Percy Dearmer.
- "Christianity and Economics", by A. D. Lindsay, LL D.

Money and Currency

- "Money versus Man", by Professor F. Soddy.
- "Lasting Prosperity", by A. G. McGregor, B.Sc.
- "Planned Money", by Sir Basil P. Blackett.

Industry and Economics

- "Man to Man", by John Leitch (published 1920).
- "Some Economic Factors in Modern Life", by Sir Josiah Stamp.
- "Onward Industry", by James D. Mooney and Alan C. Reiley.
- "Towards Industrial Recovery", by Hugh Quigley.
- "Rationalisation of Industry", by A. P. Young, O B.E. (Lecture to Rugby Engineering Society, 1929).
- "Looking Forward", by Franklin D. Roosevelt.
- "Recent Industrial Tendencies", by H. G. Hughes, B.Com., The Mather Lecture (1930).
- "Successful Living in the Machine Age", by Edward A. Filene.
- "Socialisation and Transport", by the Rt. Hon. Herbert Morrison.
- "Government in Transition", by Lord Eustace Percy.
- "Whither Industry?", by G. D. H. Cole. (Series of articles in April and May 1934 in *News-Chronicle*.)
- "Industrial Britain", by John Hilton. (B.B.C. Booklet, 1934.)

Towards a Planned Economy

- "Forward from Chaos", by A. P. Young, O B.E.
- "Reconstruction", by Harold Macmillan, M.P.
- "Plan or no Plan", by Barbara Wootton.
- "Industrial Control Tendencies", by Sir Felix J. C. Pole. (Address to Manchester Luncheon Club, 29th November 1933.)
- "A Policy of Prosperity", by Israel M. Sieff. (Series of five articles in *Morning Post*, 16th to 20th April 1934.)

Industrial Leadership and Education

- "Business Leadership", by Henry C. Metcalf.
- "Education for Business Management", by Dr. J. A. Bowie.
- "Management of To-morrow", by L. Urwick.
- "Fundamentals of Industrial Administration", by E. T. Elbourne, M.B.E.
- "Education for Industry and Commerce in England", by A. Abbott, C.B.E.

TWENTY-FOURTH ANNUAL GENERAL MEETING AT MANCHESTER

The Annual General Meeting of members was held at the Institute, 16 St. Mary's Parsonage, Manchester, at 3.0 o'clock on Wednesday, May 16th. The President, Sir William Clare Lees, O.B.E., J.P., occupied the chair, supported by other officers and members of Council. There was a representative gathering of members.

The minutes of the previous meeting having been submitted and approved, the President said that he proposed to proceed to the election of President, as the President-elect, Sir Thomas Robinson, O.B.E., J.P., had another engagement and would be glad to be able to leave as soon as possible. Proposing the election of Sir Thomas Robinson, Sir William said he did so with pleasure as the President-elect was not only a textile man but had a very wide and intimate acquaintance with wool, cotton, and rayon He was well known as a man to whom the Institute could confidently look as a worthy occupant of the office of President. He expressed the hope that Sir Thomas's year of office would be more effective than his own. He need scarcely remind them that his services had been in demand in connection with other duties which he thought were performed in the interests of all.

Mr. Frank Wright (Fellow), Chairman of the Council, seconded the proposal and said he did so not only because of Sir Thomas's standing and ability in textiles but because of his noteworthy services in Parliamentary and Municipal work. It was a fortunate thing for Stretford that such a man as Sir Thomas Robinson was available as first Mayor of the newly-chartered borough Mr. Wright said he wished to remind Members present, this being one of the rare occasions on which it was possible to speak to them, that the Institute's Charter had imposed upon the Institute a duty and a responsibility. That duty lay in the matter of the award of Diplomas (Fellowships and Associateships) and the standard set for these was high though not, in his opinion, too high. It was fitting, therefore, continued Mr. Wright, that the Institute should look to the top in seeking the services of a President, as this was but the due of all those who, by self-sacrificing work, had founded and developed the Textile Institute on such a high plane. He was satisfied that, in Sir Thomas Robinson, the Institute had found a President upon whose appointment they might be congratulated.

The election was then declared carried unanimously, and the Presidential badge of office handed to the newly-elected President.

Sir Thomas Robinson, after apologising for the circumstances of other engagements which made it necessary for him to disarrange the programme, said that he had all his life had connection with and an interest in textile technical education. He was, therefore, proud to be associated with an Institute charged with such important work in this connection. On looking over the Institute's Charter and history, he felt bound to add that the objects the founders had set before them seem to have been always kept to the forefront, and, so far as possible, achieved to a noteworthy extent. He could and did assure all members that he was honoured to be elected President of this Institute.

The Council's Annual Report and Balance Sheet—which appeared in this *Journal* in the March issue—was proposed, seconded and adopted.

The Hon. Treasurer, Mr. W. W. L. Lishman, reporting on the financial position of the Institute, said—"The Finance Committee have given careful consideration to the balance sheet and accounts and concluded that in all the circumstances the records are satisfactory. A small adverse balance appears on the revenue account for the year, which increases the total of the accumulated amount of excess expenditure over income. Fortunately, the whole of the amount is provided for by a reserve investment due to excellent foresight of the Committee in conserving the finance. Obviously, the continuance of an adverse balance on the revenue account cannot proceed indefinitely. The position is improving, however, and I am hoping that even the small loss of last year may not recur in the current year

Photo] [*Carl Fales*

Sir THOMAS ROBINSON O.B.E. J.P.

Elected President of the Textile Institute, May 1934 and that our reserve investment may be fully retained. The accounts are presented in detail for the information of all members and I need not comment further upon them."

This report, together with the Auditor's report, balance sheet and accounts, was adopted and a record of thanks to all members of the Institute's staff was made.

Mr. John Crompton (Fellow and Vice-President) proposed and Mr. S. Watson (Fellow) seconded that the best thanks of the Institute be accorded to the retiring President, Sir William Clare Lees. This was accorded with hearty acclamation.

In response, Sir William said he regarded it as a great honour that his name should be enrolled on the list of distinguished men who had previously held the presidential office, because he was convinced that the Institute would continue to rise in strength and influence. When in India recently, he was very much struck with the enormous progress in technical ability since a previous visit eight or nine years ago. In Ahmedabad, this was particularly noticeable by the use of finer counts and the work performed in dyeing and bleaching. That step forward meant that we had to go still further. As transitional periods arose, we had to adapt our industry to new requirements and specially train and educate those who were to be responsible for the direction of technical skill. The work of the Textile Institute, done quietly and unostentatiously, was carried on both well and efficiently, and the industry should be grateful to all those officers and members who devoted so much time and thought towards deeper insight into the technical and scientific problems concerning textile manufacture.

Messrs. W. Frost (Fellow), E. Midgley (Fellow) were re-elected and Mr. T. Morley elected, Vice-Presidents.

The General Secretary having read the result of the ballot for the election of ordinary members of Council and presented the scrutineers' report thereon, the Chairman declared the following elected for the ensuing three years—Messrs. Wm. Wilkinson (Blackburn), Wm. Davis (Nottingham), H. C. Barnes (Manchester), F. Wright (Bolton), H. Nisbet (Manchester), A. W. Stevenson (Galashiels), W. W. L. Lishman (Todmorden), Wm. Howarth (Bolton), J. H. Strong (Blackburn), and Fletcher Chadwick (Preston).

Messrs. Arthur E. Piggott, Son & Southworth were re-elected Auditors.

NOTES AND NOTICES

Institute Scholarship Holder

The second scholarship holder of the Institute, Mr. Wm. Graham, has now reached the concluding stage of his three years of technical training and special works experience in weaving departments. As reported to the May meeting of the Finance and General Purposes Committee, this scholarship holder is now pursuing three months of voluntary engagement in the linen industry at Belfast, having previously spent three months in worsted and other weaving in Yorkshire and six months in works concerned with the silk industry in France. On award of the scholarship, Mr. Graham was engaged in a special course of training at Manchester College of Technology for two years, which period was attended with highly satisfactory examination results. That training with subsequent experience and also pre-scholarship occupation as an automatic loom weaver, should make him well-fitted for a post of responsibility in the weaving industry. The scholarship period will terminate at the end of July. Meanwhile, the Institute would be glad to hear of any proposal for the engagement of his services—particularly in the Lancashire cotton industry.

Institute Membership

At the May meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—M. E. Haskell, A.M.I.Mech.E., M.A.S.Mech.E., M.A.I.E.E., Department of Industries, Old Custom House, Bombay, India (Industrial Engineer to Government in Department of Industries); T. E. Thompson, Hons. B.Sc., M.Sc., "Linton", Westwood Crescent, Grange Park, Bingley

(Works Chemist, Airedale Combing Co. Ltd.); *Junior*—R. M. Gimson, Wandale, Knighton Road, Leicester (in charge of testing room, B. Russell & Sons Ltd., Leicester); K. N. J. Loveless, Devonia, Friern-Watch Avenue, North Finchley, London N12 (Salesman, Austin Reed Ltd.); K. Taylor, 7 Primula Street, Bolton (Assistant Textile Designer, Walter Mather & Co. Ltd.); G. A. White, "Colwyth", Montserrat, Bolton (Cotton Doubling Overlooker, Wm. Heaton & Sons Ltd.).

Inquiries

We have received an inquiry as to the existence of (by whom made, patented, etc.) a machine for pulling or drawing horsehair. Any member who can supply particulars is asked to send these to the Institute in the first instance

REVIEW

A History of British Carpets; from the introduction of the craft until the present day.

By C. E. C. Tattersall (Department of Textiles, the Victoria and Albert Museum, London). Published by F. Lewis Limited. (Pp. 182. Price 2 gns.)

This book deals extensively with a subject that has, so far, only received a section in more general works, and the excellence of the illustrations alone makes it extremely valuable to the student. As might be expected from his other work, Mr. Tattersall's history is delightfully written, and the book is admirably produced; in particular must be mentioned the very pleasing line drawings and diagrams in the text, and the fine layout of the page.

Although this pictorial excellence gives the book a sort of unity, the subject matter divides itself sharply into two parts. The first and greater section starts with a broad outline of the development of carpet making in the East, and the social conditions which led to the importation of carpets into England. The wealth of detail that follows in the history of the English-made carpet renders these chapters fascinating, ont only for the vast amount of information collected and supplied in a most readable form, but for the glimpses they give of life in England in the sixteenth and succeeding centuries. The technical side of carpet making both by hand and by machine, is also presented, and a brief statistical survey made of present conditions in the industry.

The other part of the book, nearly a third, is given over to the history of present-day carpet-making firms, with illustrations in colour of their products. While the pictures of reproductions of Persian and other Eastern carpets show that the British manufacturer is still unsurpassed in this direction, it is regrettable that much of the original design shown is sharply at variance with the principles of design so well set out in the first chapter. In the carpets of contemporary design there is, for instance, a frequent imitation of natural form, particularly landscape, almost always unpleasant in a thing made to be walked upon. Colour too is sometimes florid, and often lifeless and heavy; and the designs labelled "modern" or "modernistic" show a borrowing of mannerism from the Continent, rather than an understanding of present-day thought in creative work. As an exception to this criticism must be mentioned the design of the carpet in plate LX (Messrs. John Crossley & Sons Ltd.) a pattern which suffers somewhat in effect through reduction, and is in reality much more satisfactory; and the rug in Plate LXXXIV (Messrs. Alexander Morton, Sons & Co.) though this latter is of course handwoven on the tapestry method.

It seems a pity that so little should be shown of our progressive contemporary design in hand-tufted rugs, which in time may be expected to have a considerable influence on the design of the machine-made product. One would have liked to see included, for example—to name only two groups—illustrations of the interesting Dorn monochrome designs, or the pleasant Scotch hand-tufted rugs, with their carefully chosen tones and good colour. For anyone becoming acquainted with the British carpet through the medium of this book, the inclusion of such illustrations would have helped to balance the picture of what is being done by designers in present-day Britain, and to suggest that the intelligent use of modern forms can yet result in designs which are in keeping with our national taste and tradition.

A. M.

THE JOURNAL OF THE
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PROCEEDINGS

ANNUAL CONFERENCE OF THE INSTITUTE

GRANGE-OVER-SANDS 23rd-25th MAY 1934

This Conference was the third in a series which commenced with that held at Leamington Spa in 1932. The Council of the Institute approved of the general proposal to conduct Conferences on the plan then established. This plan is, briefly, to adopt a general subject for the Conference and to invite papers from individual contributors on various aspects of that central subject. Subsequently such contributions have appeared in the Proceedings section of the *Journal.*

At Leamington the general subject was "The Testing of Textiles" and at Harrogate last year, "Finishing" formed the central theme upon which papers were delivered. These two subjects comprehend, virtually, the same field as Sections 5 and 4 of the *Journal* Abstracts, and, in addition, cover the same sections of the syllabus for the Institute's Examination (Part II) in General Textile Technology.

The Grange-over-Sands Conference this May fell into line with this policy and the subject chosen, "The Conversion of Yarns into Fabrics" covers Section 3 of both Abstracts and Syllabus. The full series of Conference papers appears in the Proceedings of this issue, and in no other publication, as it has been indicated that such a concentration would be appreciated. Extra copies of the full papers will be available bound separately at rates given in the advertisement pages of this issue. Already orders for these extra copies have been received to an extent which the Publications Committee regards as very satisfactory and as indicative of a big demand for the volume when ready. Every member, therefore, interested in this aspect of the Institute's work can assist by purchasing one or more copies of the special volume and by bringing it to the notice of others, particularly students.

In connection with this issue, extra advertisement revenue has been sought to help meet the additional costs and the response has been good; one member in replying to a request for an advertisement wrote "feeling that as members of of the Institute we ought to contribute we will take . . . . in the special issue mentioned." This is but one instance and the advertisement pages themselves indicate the extent of the support given by the members as a whole.

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SOME NOTES ON THE CONSTRUCTION AND APPLICATION OF IMITATION BACKED AND IMITATION DOUBLE WEAVES

By A. Yewdall, F.T.I.

(Department of Textiles, The University, Leeds)

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In designing for woollens and worsteds, imitation-backed and imitation-double weaves do not appear to receive anything like the attention they merit, either constructionally, or in their application to different classes of fabrics. They provide, however, considerable scope, not only in the production of a large variety of weaves suitable for fine worsted coatings, but also for the building up of colour and weave effects in both fancy woollens and worsteds.

Imitation-backed weaves seem to have been originated in Austria by Franz Donat,[1] who worked out methods of converting simple twills into imitation-backed structures, and showed, also, how other classes of single weaves could be used for these structures by first determining the size of the required design, and then building it up from an extended sateen base. Though he worked out a large number of weaves he gave no particulars of yarn counts and settings necessary for their production in the loom.

Imitation or interchanging double weaves, built up on a sateen base, were apparently first made by Roberts Beaumont,[2] who showed their possibilities with regard to the making of worsted coating cloths by suggesting suitable counts and settings.

Practically all kinds of simple weaves can be used for the face effects of both the backed and double types of these structures, and the results of many series of experiments have shown that the routine methods of their construction may be standardised and considerably simplified.

PART I—IMITATION BACKED WEAVES

These weaves, like true backed structures, may be made on both the warp and weft principles, and their thread units, also, may be built up to correspond with structures arranged on the 1-and-1, 2-and-1, and 3-and-1 systems of thread distribution. The yarns, however, used for these arrangements must be of the same counts, because they appear on both the face and back of the texture in turn. The counts of warp and weft, may, of course, be different from each other.

The methods of setting these weaves in the loom approximate to those used for their corresponding true backed weaves; fabrics constructed on the imitation warp-backed principle are, therefore, more economical to produce, owing to the fewer number of picks per inch they require when compared with those made on the weft principle.

Construction of Imitation Warp-backed Weaves

Simple Twill Weaves

(*a*) 1-*and*-1 *System of Thread Distribution*—All twills running at an angle of 45° may be converted into imitation backed weaves, and Fig. 1 shows the routine stages required in the construction of a weave made on the 1-and-1 system with the warp threads forming the Prunelle (or 2-and-1) twill on the face and a sateen weave effect on the back. It will be seen that there are practically two repeats of the face weave to one repeat of the sateen weave on the back. The odd-numbered sateen is necessary in order to cause the warp threads to change from the face to the back of the fabric in turn. In making the weave the following routine may be followed.

1—Commence the first twill on the first thread and pick of the point paper, and continue it on the succeeding odd threads, as shown in Fig. 1A.

2—Commence the second twill on the second thread leaving a space, sufficient to allow a weft twill of the correct size, and continue it on the even threads until it runs into the twill on the odd threads, thus completing the weave as seen in Fig. 1B.

The starting points for each of the face twills are marked in solid squares, and all the marks indicate warp lifts.

Fig. 2, also made according to the same routine, imitates the 2-and-2 twill on the face and a sateen effect on the back.

Fig. 1 is considered by some to imitate the 2-and-2 twill instead of the Prunelle. An examination of the two weaves, however, shows that this view is erroneous because the space between the two warp twills is not sufficiently large to represent the weft 2-float of the former twill. In the fabric, also, Fig. 1 yields a distinctly warp-faced effect.

Figs. 3 and 4 are obtained respectively from the 3-and-1 warp twill and the 3-and-2 weft twill.

(*b*) 2-*and*-1 *System of Thread Distribution*—Fig. 5 shows the three stages required in the construction of a weave arranged on the 2-and-1 system with the 2-and-2 twill on the face and a sateen back. There are practically three repeats of the face weave to one repeat of the sateen back. The following is the routine.

1—Commence the first twill on the first two threads, miss the third (considered as a backing thread), and continue as before, missing every third thread, as shown in Fig. 5A.

2—Commence the second twill on the second and third threads leaving the correct space above the first twill for the weft float (Fig. 5B).

3—Commence the third twill on the third thread and continue as before, this completing the weave (Fig. 5C).

On examining the completed weave it will be seen that the three twills form an endless band, the second twill running into the first, and the third running into the second.

(*c*) 3-*and*-1 *System of Thread Distribution*—Weaves made on this system are built up in the same general manner as already described, but there are four stages in their construction, four twills being necessary in order to complete them. In making a weave commence the first twill on the first three threads, miss the fourth, and continue in that order. The other twills commence on second, third, and fourth threads respectively.

Figs. 6 and 7 are both made on this system, the former imitating the 2-and-2 twill on the face, and the latter imitating the weft Prunelle.

An examination of the weaves made on these three systems reveals that the size of any design derived from a simple twill may be determined as follows.

System of Arrangement		Determination of Size
1-and-1	...	(Threads in face weave × 2) + 1
2-and-1	...	(Threads in face weave × 3) + 1
3 and-1	...	(Threads in face weave × 4) + 1

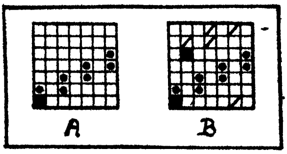


FIG. 1

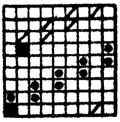


FIG. 2

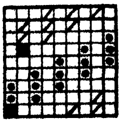


FIG. 3

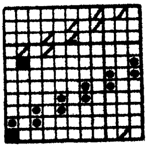


FIG. 4

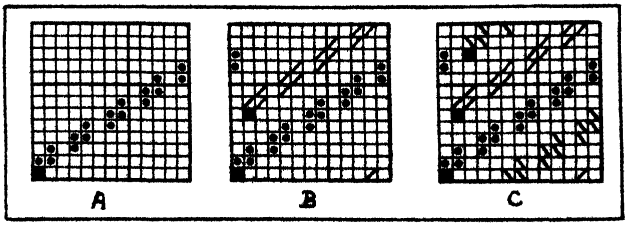


FIG. 5

When the size of any required weave is predetermined in this manner, the routine of construction may be considerably simplified by commencing the first twill—in its appropriate order—and continuing it within the prescribed area until the design is complete. The starting points of the other twills need not be considered, because, as already pointed out, the component twills form an endless band.

Mat or Hopsack Weaves

There are three distinct methods of converting mat weaves into imitation backed structures arranged on the 1-and-1 system. A common method is to make them on twice the number of threads comprised by the single weave +1. The weave is commenced in the same manner as just described for simple twills, and is continued over the required number of threads and picks until it is complete. Owing to the grouping of the thread units in the mat weave the imitation backed structure requires more picks than threads for its completion. Fig. 8 shows the 2-and-2 mat converted into an imitation backed weave in this manner. It will be seen that the mat figures or squares move in twill order, first on the odd and then on the even series of threads, until the weave is complete, this necessitating twice as many picks as there are threads.

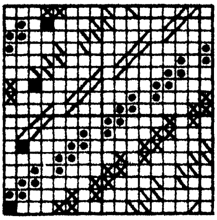


Fig. 6

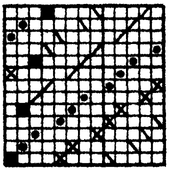


Fig. 7

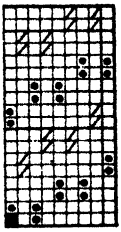


Fig. 8

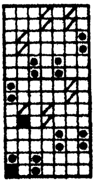


Fig. 9

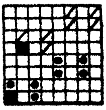


Fig. 10

Another method of construction is to follow the first rule explained for making twill weaves by commencing one series of mat figures in twill order on the odd threads, and a second series on the even threads, leaving sufficient space for the weft floats.

Weaves made in this manner complete on twice the threads comprised in the single weave −1. They yield much more satisfactory fabrics because the mat figures are brought closer together, and the surface twill lines formed by the larger sateens obtaining in the previous method are practically eliminated. Fig. 9, based upon the 2-and-2 mat, illustrates this method of construction.

A third method, illustrated by Fig. 10, eliminates the possibility of surface twill lines by running one set of mat figures on the odd and the other on the even threads, and not changing them over to the opposite series as in the other methods. These designs are always complete on an even number of threads, and are square, having the same number of picks as threads. With this arrangement, there is, of course, no sateen pattern formed on the back of the texture, though the long floats maintain the semblance to a backed structure.

Figs. 11 to 13, derived from the 3-and-3 mat, are made respectively on the three methods just explained.

Small Fancy Weaves

(*a*) 1-*and*-1 *System*—Small fancy twills and sateen derivatives may be made on twice the number of warp threads +1. In many cases, however, this method of construction does not yield very satisfactory imitations of the face weave because of the strong surface twills formed where the warp yarns interchange, these being due to the two series of weave figures not being close enough together. Most 8-end weaves produce better structures when made with twice the number of threads contained in the base weave −1.

Figs. 14 and 15 are obtained from the Mayo twill (Fig. 14a), the former being made on 17 threads (twice 8+1), and the latter on 15 threads (twice 8−1). In both examples the weave requires twice as many picks as threads for its completion. Fig. 15 yields a firmer fabric with a more perfect face.

Figs. 16 and 17 are made in the same manner as Fig. 15, the former being obtained from the 8-end twilled mat (Fig. 16a), and the latter from a small reverse weave (Fig. 17a).

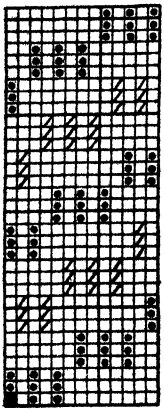


Fig 11

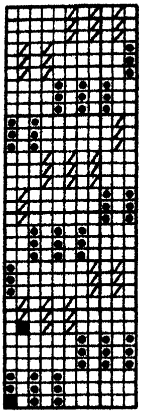


Fig. 12

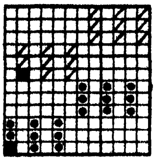


Fig. 13

Fig. 17a

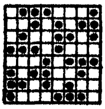


Fig. 14a

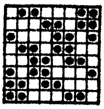
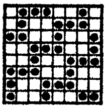


Fig. 16a



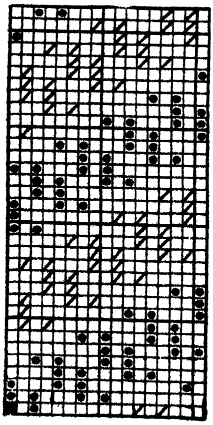


Fig. 14

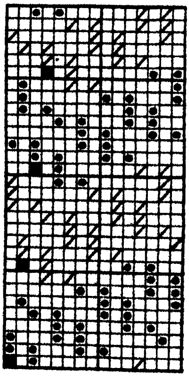


Fig. 15

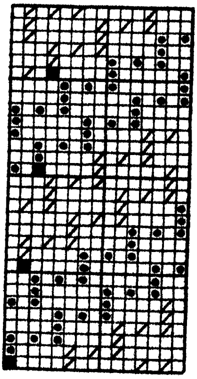


Fig. 16

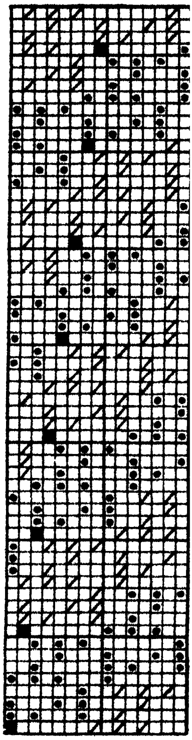


Fig. 17

An examination of these last three designs reveals that the commencing places for the second repeat of the basic weave on the even threads always occurs on the ninth pick, which is equivalent to starting them at the beginning of a second repeat of the picks of the basic weave itself. From this, a general rule may be formulated —applicable to all designs except pure twills, as follows—

> "Begin the design on the odd and even series of threads in the usual manner, but always start the second series at the beginning of a second repeat of the picks of the basic weave."

This rule may be used also, for constructing designs arranged on the 2-and-1 system.

The number of picks on which these designs repeat is governed by the structure of the basic weave. For example, Figs. 15 and 16 require twice as many picks as threads because their component figures are grouped in 2's. In Fig. 17 these figures are grouped in 4's, hence the design requires 4 times as many picks as threads. The solid black squares in the designs denote recurring repeats of the basic weave; in Figs. 15 and 16 there are 4 repeats, spaced alternately on the odd and even threads; in Fig. 17 there are 8 repeats.

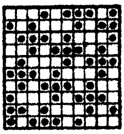
Figs. 18 and 19 are obtained from two 10-end pinhead weaves (Figs. 18a and 19a). They are both constructed according to the simplified rule just explained, the second repeat of the basic weave commencing on the eleventh pick in each design, as indicated by the black squares.

Figs. 20, 21, and 22 are obtained from weave derivatives (Figs. 20a, 21a, and 22a respectively), each reproducing the peculiarities of their basic construction in the number of picks on which they repeat in the imitation backed structure.

(*b*) *2-and-1 System*—Designs from 8-end weave bases may be made in several ways. In one method they may be made to repeat on $1\frac{1}{2}$ times the number of threads in the face weave +1, i.e. on 13 threads with (generally) twice that number of picks. The weave is commenced—as in twill construction—on the first three threads of the required design as shown in Fig. 23, obtained from the Barathea twill (Fig. 23a). With some weaves this method is not feasible, but, as they all repeat on 13 threads, it is only necessary to commence one series of figures and continue it until it repeats. Fig. 24, obtained from the Mayo twill (Fig. 14a) is constructed in this manner, as also is Fig. 25, obtained from the Barathea.

A comparison of Figs. 23 and 25 shows that in the former all the component figure-squares are split, while in the latter they are split on alternate twills only. The first arrangement will yield a more even surface in the fabric.

FIG. 18a



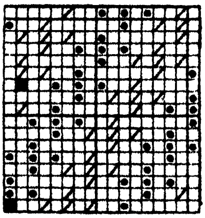


FIG. 18

FIG 20a

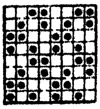


FIG 22a

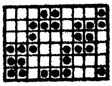


FIG. 19a

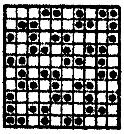
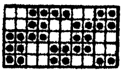


FIG. 21a



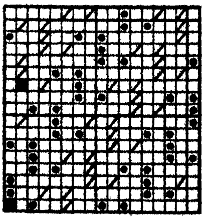


FIG. 19

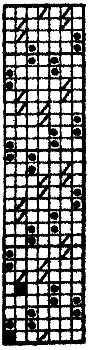


FIG. 20

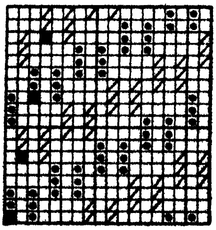


FIG. 21

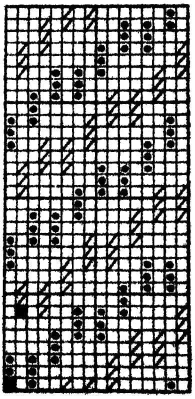


FIG. 22

Most of the 8-end weaves may also be made on 11 threads (1½ times the number of threads in the basic weave −1) by applying the rule with regard to the weft repeats, and Fig. 26, obtained from the Barathea, is constructed in this manner. The black squares show the commencing positions of the three twills, there being a space of 8 picks—corresponding to the number of picks in the basic weave—between them.

A further comparison of the three weaves derived from the Barathea shows that Fig. 23 will yield the firmest fabric, because the warp-lifts on each pick are all isolated and the backing floats are shortest. Fig. 26 comes next in order, and Fig. 25 comes last, this being the loosest structure.

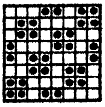
Figs. 27 and 28 show two ways of arranging the Mayo on 11 threads and 22 picks. The former is unsatisfactory because the ends of the figure components overlap and join; in the latter this fault is obviated by splitting the figures, the first series of twills beginning 1 face, 1 back, 1 face, instead of 2 face and 1 back.

Setts for Imitation Warp-backed Weaves

As already stated these weaves are set on similar lines to true backed weaves, and the following table gives practical setts for some of the different varieties of structures. The counts of yarn for each sett = 2/40's worsted.

Figure No.	Threads per inch	Picks per inch	Reed Width in.	Weight per yard oz.
1	96	58	64	15
2	108	60	64	16
4	116	64	64	18
5	88	54	64	14
6	108	60	65	17
7	84	54	65	13
14	120	72	64	18
15	96	60	68	16
24	80	54	68	14

FIG. 23a



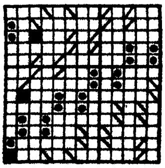


FIG. 23

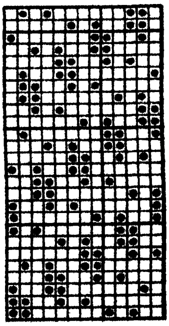


FIG. 24

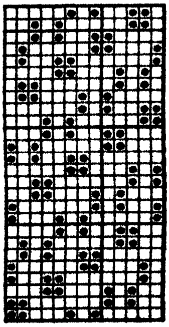


FIG. 25

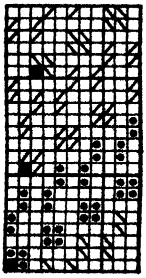


FIG. 26

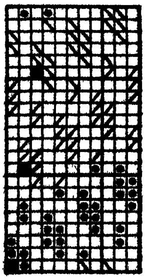


FIG. 27

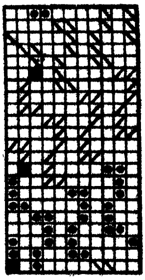


FIG. 28

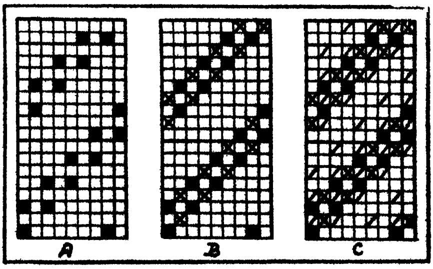


FIG. 29

Imitation Weft-backed Weaves

The same methods of construction apply as for imitation warp-backed weaves, but, of course, it is the weft and not the warp that forms the pattern on the face and back of the fabric alternately. All the designs given above, therefore, become imitation weft-backed structures when given a quarter turn. In practice, however, they would require adjustment in order to make the twilled figures incline to the right. Also, as the marks on the point paper now denote "weft up" instead of "warp up" the blanks, and not the marks require pegging when preparing for weaving.

A constructional feature militating against the use of some of these weaves is that many of them occupy more threads than picks, and, therefore, require a greater number of heald shafts for weaving than if they were made on the warp principle.

In the following table, suitable counts of worsted yarns and setts are given for certain of the above weaves when woven as imitation weft-backed structures.

Figure No.	Counts of Yarn	Threads per inch	Picks per inch	Reed Width in.	Weight per yard oz.
2	2/30's	56	104	68	21
4	2/40's	70	112	66	17
7	2/50's	80	84	68	12
11	2/50's	80	120	66	15
16	2/50's	80	96	66	14

PART II—IMITATION DOUBLE WEAVES

These structures possess certain structural resemblances to imitation backed weaves, insomuch as either the warp or the weft yarns interchange to form the pattern on the face and back of the cloth alternately. The fabric, however, has the appearance of a perfect double structure.

The weaves are all constructed on the 1-and-1 system of thread distribution, and there are three distinct methods of arranging the warp and weft yarns, as follows—

1—One warp, interchanging from face to back, and two distinct wefts, one interweaving on the face and the other on the back.

2—Two distinct warps and an interchanging weft.

3—One warp and one weft only, both of which interchange.

The first method provides the most advantages in practice; firstly, the weaves, being smaller warpways than similar designs made by the other two methods, do not require so many heald shafts in weaving; second, as each warp thread interlaces equally there is no difference in "take-up", so only one warp beam is necessary; and third, the two distinct wefts allow a lower quality yarn to be used for the back of the fabric. In the second method the two separate warps, of course, allow a different quality of yarn to be used for the back.

Construction of Weaves with an Interchanging Warp

The routine of construction is practically the same as for ordinary double weaves, and may be outlined as follows—

1—Determine the size of the required design. This is obtained by adding another warp thread to the number contained in its corresponding true double structure. The additional thread is required in order to make the warp interlace alternately with the two wefts. The number of picks contained in the design is always at least double that of the threads, this being on account of the warp changing from the odd to the even series of threads when interchanging.

2—Commence the face weave on the odd threads and continue it until it changes over on to the even series and completes. It may change from the odd to the even series several times before it runs out, this depending upon the structure of the basic weave.

3—Commence the backing weave on the even threads and continue it until it changes over and repeats.

4—Add marks to lift up the face warp on the backing picks and complete the design.

Stitching by any of the ordinary methods is unnecessary because this is effected automatically by the warp as it changes from the face to the back of the cloth.

Fig. 29 shows the stages of construction for an imitation double 2-and-2 twill weave. As its corresponding true double structure occupies 8 threads and picks, the necessary additional thread makes the required design occupy 9 threads, this number being doubled in the weft. *A* shows the face weave (marked in black squares), *B* shows the backing weave (marked in crosses), and *C* shows the structure completed by the addition of the warp "lifters" (marked in strokes).

Figs. 30 and 31 are also made in the same manner, the former having the 3-and-2 warp twill on the face and the 3-and-2 weft twill on the back, and the latter having the 3-and-3 twill on both sides.

Fig. 32 is an imitation of the double 2-and-2 mat, the design occupying 9 threads and 36 picks. The face weave is clearly seen to be arranged on a 9-end extended sateen base, and as a consequence appears to be twilled slightly. With a suitable sett, however, this defect will not be observable in the fabric.

Figs. 33 and 34 are obtained from small fancy twills (Figs. 33a and 34a) respectively, and Fig. 35 is constructed from a weave derivative.

Some double weaves when converted into imitation double structures complete on a large and unwieldy number of picks, but by commencing the face weave and running it over the threads for a few repeats a sufficient indication can be obtained as to the total number required for its completion. The designer can then decide whether it is worth continuing; it may not merit the time taken if it requires a very long pattern chain for weaving.

Construction of Weaves with an Interchanging Weft

The routine of construction is the same as that just described, but the dimensions are reversed, an extra pick being added to the number of picks contained in the corresponding true double weave. Designs made according to this method, therefore, complete on more threads than picks, and if of large size cannot be produced in dobby looms.

Fig. 36 is made with an interchanging weft and two distinct warps, the structure imitating a double 2-and-2 twill. It is complete on 18 threads and will, therefore, require that number of heald shafts in weaving. Its corresponding weave, made on the interchanging warp principle requires half that number only.

Construction of Weaves in which both Warp and Weft Interchange

These structures require twice the number of threads contained in their corresponding double weave +1, and a multiple of this number for the picks. They yield much firmer fabrics because both series of yarns interchange, and form, therefore, twice as many stitches as in fabrics made with one series only interchanging.

Fig. 37 illustrates this kind of structure, and imitates a 2-and-2 twill.

In making designs on this principle one twill is commenced on the odd threads and picks, and a second twill is commenced on the even threads in such a position at the start that it leaves sufficient space for the necessary weft float.

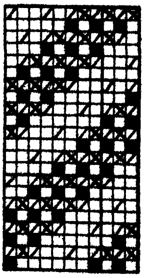


FIG. 30

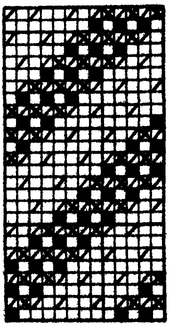


FIG. 31

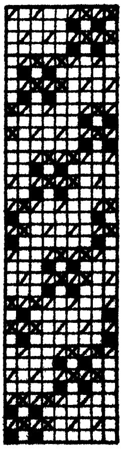


FIG. 32

(In Fig. 37 the first twill starts on the first thread and pick, and the second one starts on the ninth thread and second pick.) Both twills are continued until the design is complete.

FIG. 33a

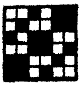


FIG. 35a

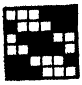


FIG. 36

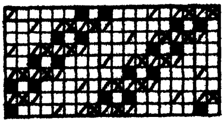
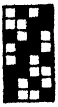


FIG. 34a



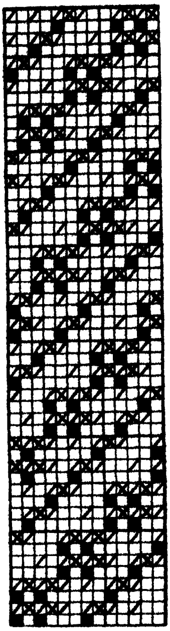


FIG. 33

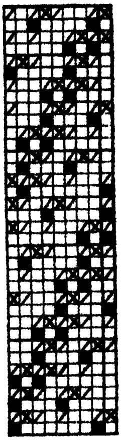


FIG. 34

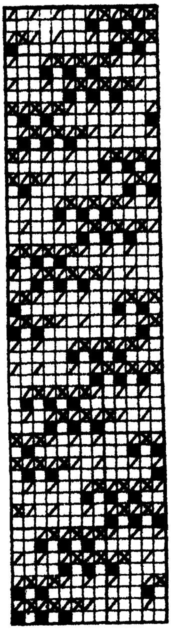


FIG 35

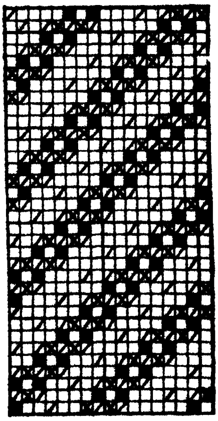


FIG. 37

Setts for Imitation Double Weaves

Imitation double weaves are generally set on practically the same lines as their corresponding true double structures, and the following table give suitable counts and setts for producing Figs. 29 to 36.

Figure No.	Counts of Yarn	Threads per inch	Picks per inch	Reed Width in.	Weight per yard oz.
29	2/40's	108	108	66	22
	2/50's	126	120	68	21
30	2/50's	154	116	67	22
31	2/40's	120	96	63	22
32	2/40's	108	104	64	21
33	2/40's	132	112	64	24
34	2/50's	126	96	68	19
35	2/40's	132	120	64	25
36	2/50's	126	120	70	22

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LOOMS FOR THE SILK AND RAYON INDUSTRIES WITH REFERENCE TO THEIR STRUCTURE AND PERFORMANCE

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INTRODUCTION

Industrial history shows that the power loom has been introduced much later in the silk industry than in cotton and wool industries. This has been the case in England, where in 1870 only 22% of the silk looms were power looms, but more particularly on the Continent, and especially in Switzerland, in the silk industry of which country the hand loom was only supplanted by the power loom as late as 35 to 25 years ago. Even now in Switzerland a certain number of hand silk looms are in operation, producing bolting silk, which could not, as yet, be made in the same quality on power looms.

This retarded development is due to the difficulties connected with silk weaving; particularly refined power looms are necessary to deal with so delicate a fibre and to produce a fabric equal to the high standard expected of silk products. Therefore, power looms had to be brought to a very high degree of perfection before they proved more efficient than hand looms in this branch of the textile industry.

If a comparison is made between an ordinary loom, say weaving calico, and a loom producing silk fabrics, the particular problems encountered on the latter will become evident Whilst a cotton loom of usual width will have, as a rule, 2,000 to 5,000 warp threads, a corresponding silk loom may have up to 25,000 warp threads The silk yarns are much finer and accordingly require particularly careful treatment, though silk is in itself a very resistant and elastic material. To reduce warp stretching by the shedding motion, the depth of the shed is kept very small, without reducing its length. With the same object in view, the horizontal length of the warp, i.e. the distance from the back rest to the breast beam, is considerably augmented. The movement of the slay is unusually small, the crank radius having been reduced to something like 2¼ inches. The small shed requires a shuttle of small section.

To eliminate one point of contact between the warp and the loom, the back rest is often omitted and the beam is placed high in the frame. The delicacy of the fabric excludes the use of a sand roller and makes direct taking up a necessity. Most silk looms have an under-pick motion, particularly designed to give a soft, smooth pick; and the rather tiny shuttles are mostly equipped with sensitive tension regulators. To protect the warp threads in the lower sheds, the slay check is covered with woollen cloth and possibly paper. The quality of fine fabrics is improved by a reed, which is kept in the usual position whilst the shuttle passes through the shed and is inclined at the moment of beating up. The angle between the fabric and the reed being smaller than 90°, the fabric can give way, and the beating-up becomes particularly gentle. Notwithstanding this soft throw of the reed, silk looms are run at less picks per minute than other looms of the same reed space. The loom must be thoroughly designed in every detail and requires more accurate workmanship than looms used for less delicate fibres. Some makers give special instructions about transport precautions, to prevent the slightest distortion of any moving part.

Rayon may be woven on cotton or on silk looms. If cotton looms are in good condition and if special precautions are observed, rayon fabrics may successfully be made on them. However, experience shows that they may be woven more easily on silk looms, particularly fine qualities. Rayon is inferior to silk in mechanical strength and especially in elasticity and it is more susceptible to strains. Therefore the special properties of silk looms will prove of even greater advantage when working rayon. All that has been said above about silk weaving holds good for rayon.

In this paper, the expression silk loom is used then for real silk looms and for high-class rayon looms; as the whole development of these looms was connected with silk, it seems justifiable to call them silk looms, though they may be used just as much or even more for rayon at present and possibly in future.

As a consequence of the delicacy of the material and of the high standard demanded of the fabric, individual loom drive is being made use of on a large scale in silk industry, notwithstanding the small power required by each loom. The speed variations, necessarily occurring when shaft drive is applied, are sufficient to produce visible irregularities in the finest fabrics, or, still worse, irregularities which will show after finishing. When starting up the loom, the first pick and the first beating-up may be made with reduced speed and streaks may result. With individual drive the acceleration of the loom is much greater, the motors being especially designed with this aim in view. So that the first weft yarn beaten-up after a stop will not show any difference from others. Moreover, each loom, forming a self-contained unit with its motor, will give absolutely constant operation throughout, if the current supply is adequate.

Silk yarns being very fine as a rule and their number per length unit of the fabric very great, silk looms usually show rather small production and one weft bobbin may last for a considerable period. Therefore changes of bobbin, which may be necessary once every 20 to 40 minutes, cause far less interruptions and loss of time than on other looms and constitute a problem of subordinate importance. The efficiency of silk looms is not so much dependent on the change of weft bobbins, as on breakage of warp threads.

In the foregoing general remarks an attempt has been made to point out the differences, which distinguish a silk loom and its operation from ordinary looms. Within the compass of this paper, it is obviously not possible to deal in an exhaustive manner with the design and performance of looms suited to the difficult task described. However, the following chapters will try to explain several especially interesting details of loom structure, as designed recently by some leading loom makers, and to show the tendencies of the latest developments.

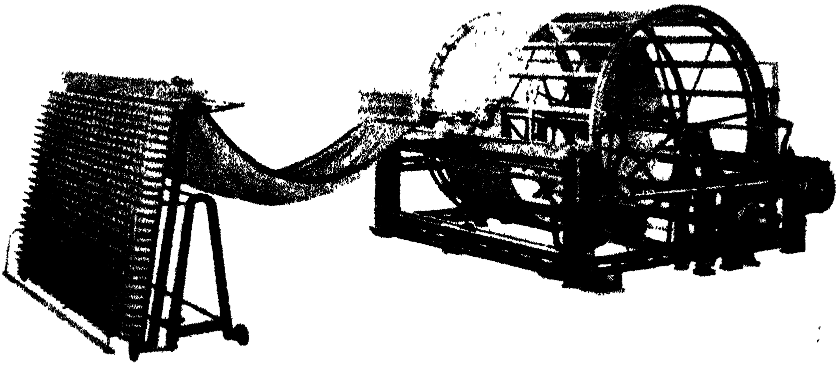


FIG. 1—Cone warping machine (Ruti) with individual drive and creel for revolving bobbins.

SOME REMARKS ABOUT WARP BEAMING AND DRESSING

The success of the weaving process is so strongly influenced by a careful preparation of the warp that a few remarks on this point seem justified.

The cone warping machine is generally used in the silk industry and has proved very successful for rayon as well. Fig. 1 shows a well-known cone warping machine, with a creel for revolving bobbins. The speed of the machine can be widely varied by change wheels, contained in a gear box, and by friction disc and roller, which makes it possible to alter the speed steadily and to drive backwards. The latest design is so improved, that the operative can control the machine without ever leaving his place. A steel band, running across the machine on its front side, serves as length indicator. It carries a very wide scale and adjustable cams, which will automatically and periodically stop the machine after a certain length. This permits the operative to pass lease bands between the threads, and the same device will finally stop the machine when the warp length has been completed.

The working speed of this machine is limited by the thread tension necessary to accelerate the revolving bobbins when starting the machine, and by the fact that the bobbins will run on a little while after the pull of the threads ceases. If the warping cylinder is retarded abruptly, the threads may become loose and entangled and much damage may result. Experience shows that the speed ought not as a rule to exceed 180 feet per minute. Much higher speeds are admissible, however, if fixed pirns are used instead of revolving bobbins, in which case the only inertia to deal with is that of the thread itself. Machines specially designed

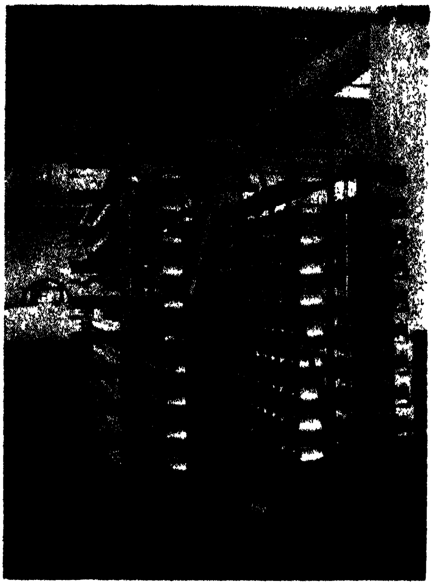


FIG. 2—Creel for fixed pirns, tapered cheeses (Benninger). Middle passage accessible, ready for creeling.

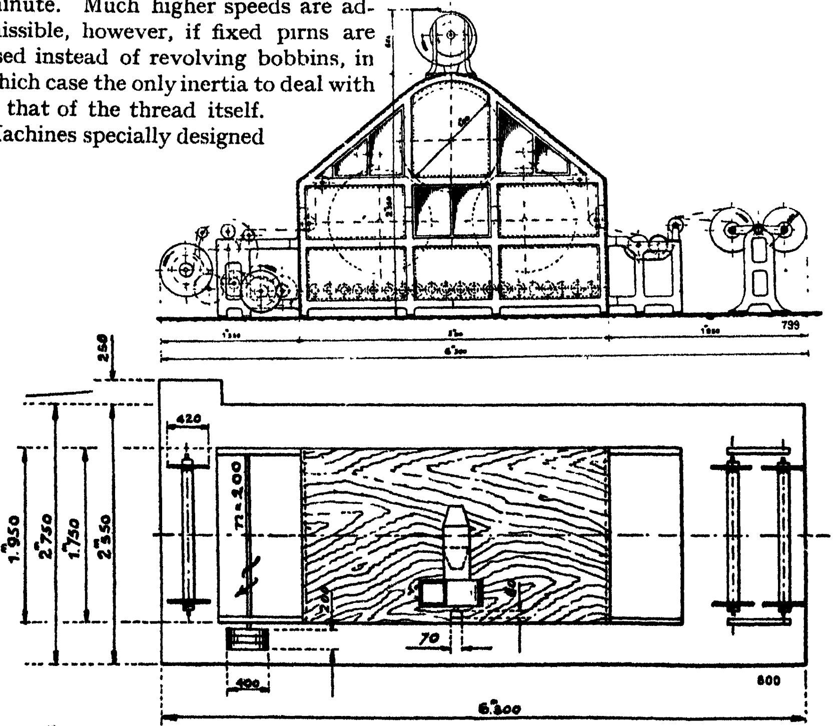


FIG. 3—Elevation and ground plan of hot air chamber sizing machine (Ruti) for rayon, schappe silk, and silk.

for this purpose are working at speeds varying from 660 to over 1,200 feet per minute and give full satisfaction. Fig. 2 shows a creel for tapered cheeses of great capacity. Incidentally the cross-wound tapered cheeses contain a far greater amount of yarn than the usual revolving bobbins, which fact also increases the efficiency. Light needles, hanging on the threads, shut a contact in case of yarn breakage and immediately stop the warping machine. Convenient porcelain yarn brakes can be adjusted individually and/or all at once. For creeling the two bobbin frames can be moved sideways, leaving a central passage for the worker (as shown), but when warping the two frames are close together in the middle of the creel, providing the necessary space for the balloon, between the fixed pirns and the yarn brakes. For high speeds a closed warping machine cylinder is of advantage, causing less ventilation.

As sizing of rayon has been the source of considerable difficulties, a few remarks may be added about this part of the warp preparation. Aiming at a machine suitable for sizing grey, as well as coloured, yarns, without impairing either the beauty of the colour, nor the shape and elasticity of the rayon, a special new design has been developed. Fig. 3 shows an elevation and ground plan of the machine. From the beam the warp is led through the size box (which may contain any suitable sizing agents—linseed oil in benzine solution, "Lojazit" solution, etc.) to the hot air chamber, heated by pipes at the bottom containing steam of 70 lb. sq. in. pressure. A special control instrument keeps the temperature constant, usually at approximately 95° C. (203° F.), whilst a fan on the roof of the machine produces a steady airflow through the chamber. The warp is led on a fairly long way round three drums, the two first of which are covered with cloth, their only function being to support the threads; the third drum, with a copper cylinder, is heated by steam of reduced pressure. In front of the hot air chamber the warp passes a counter and is immediately beamed again in the usual way.

This combined hot air and cylinder sizing machine has proved perfectly satisfactory as far as quality is concerned and thoroughly efficient, working at a speed varying from 27 to 46 feet per minute. The following details are worth special mention. Whilst one beam is being sized, a second one can be prepared, the beginning of which may be attached to the end of the first one, in order that the work can be carried on steadily. The three drums in the hot air chamber are carried on ball bearings to keep the yarn tension low, which also can be regulated by an adjustable brake on the back beam. A gear box makes it possible to run the machine on several working speeds and on slow speed.

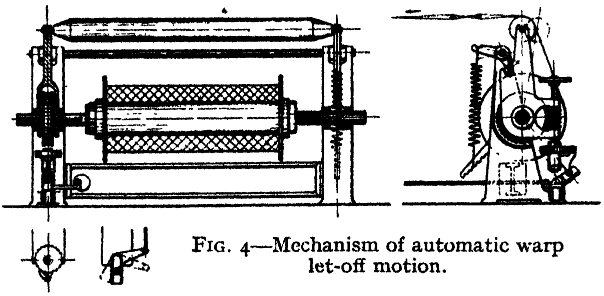


FIG. 4—Mechanism of automatic warp let-off motion.

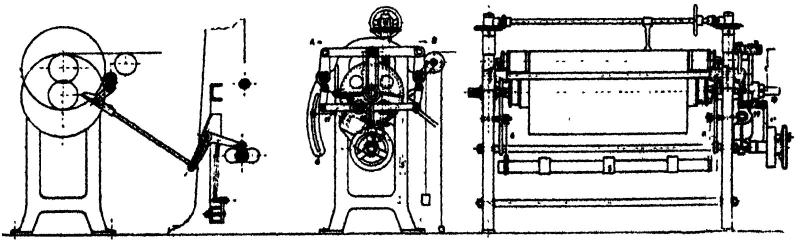
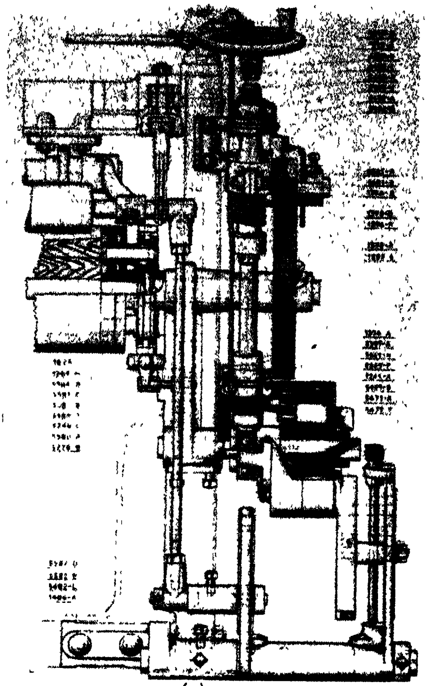


FIG. 5—Mechanism of automatic warp let-off motion and beam stand.

WARP LET-OFF AND TAKING-UP MOTIONS

To maintain a constant tension in the warp and to produce a perfectly homogeneous fabric the warp-control mechanism must work with great precision.

Though the majority of silk looms are still running with a plain frictional let-off motion—and are giving satisfaction if well cared for—successful attempts have been made to introduce automatic warp let-off motions, which will keep the warp tension constant throughout. A remarkable design is shown in Fig. 4. The bearings of the warp beam and the back beam are carried by two side frames, which can swing round a pivot at the bottom or round the warp beam axis. Two powerful draw springs, acting on bent levers, turning round two pivots attached to the framing of the loom, tend to push the back rest backwards and produce tension in the warp. The pull of the springs can be adjusted to give the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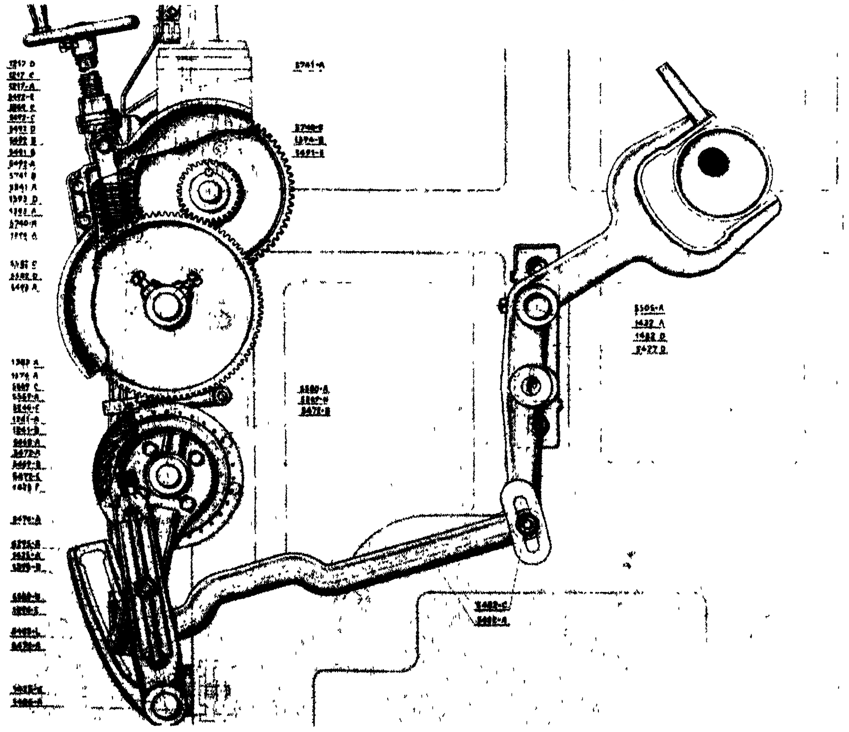
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FIG. 6—(*a*) Front view of automatic direct take-up motion (Jaeggli). (*b*) Side view of same motion (Jaeggli).

tension suited to the fabric. To let off the warp, the beam itself is turned round its axis by a worm and worm-wheel, the motion of which is influenced by the warp tension. If the warp tension increases the let-off motion augments, thus tending to reduce the warp tension to the normal value. A bent lever at the bottom rocks to and fro, being connected through a rod with the slay or a cam on the lower shaft. A slot in this lever takes on a driver, connected with the pawl acting on the ratchet wheel. It is easily seen that the motion of the pawl is dependent on the warp tension; if this increases, the whole frame becomes inclined towards the loom and the driver will take a position in the slot farther off the axis.

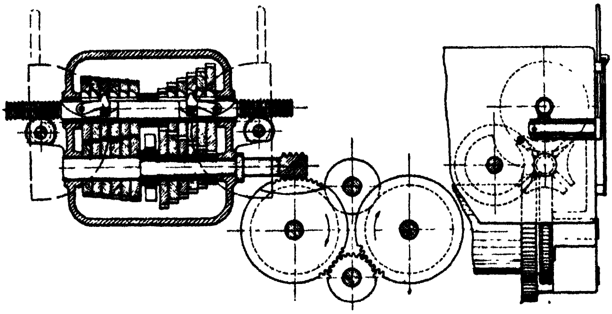

FIG. 7—Gear box for adjustable take-up motion (Saurer).

In the mechanism just described, a back rest is made use of, which may be of some disadvantage when working very fine yarn. The warp let-off motion shown in Fig. 5, particularly designed for silk looms, is devoid of a back rest, the warp leaving the warp beam horizontally at the height of the fabric. This makes it necessary to raise the warp beam, when its diameter has become smaller, in order to keep the warp always on the same level. When turning the shaft on the top of the beam stand, both warp beam bearings are screwed up or down the same amount, together with the mechanism for the let-off motion. The warp tension is kept constant, independently of the diameter of the warp beam, by a special device. The draw produced by the weights, 5, and the lever, 6,

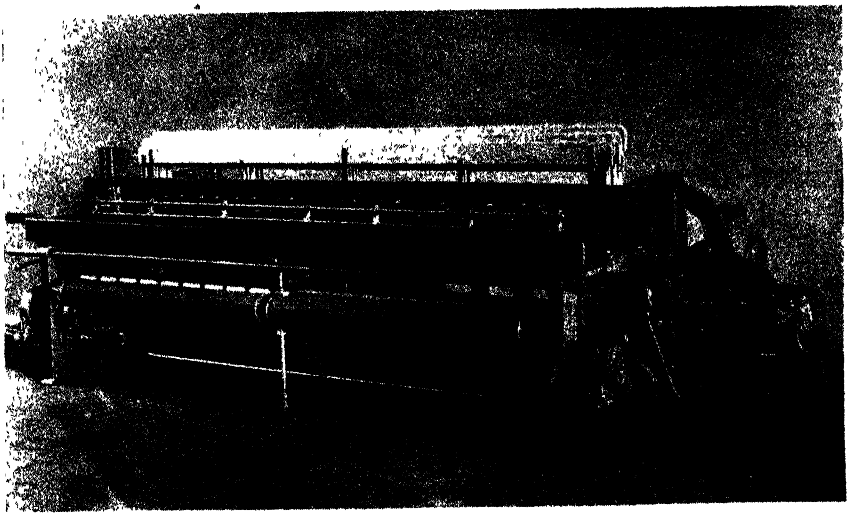

FIG. 8—Smallware loom (Saurer). Stringless positive shaft drive from tappets at right end of loom. Two independent take-up motions.

is transmitted through the horizontal rod AB on the frame of the let-off mechanism; AB carries a sliding block which transmits the force on the vertical slot in the frame. The warp and the rod AB always having the same height, the warp tension is equal to the constant force acting on the slot of the frame. In other words, the distance "c" is always equal to the radius of the warp beam. The force acting on the frame of the let-off mechanism is transmitted to the warp beam unaltered, as the frame pivots round the beam axis, and as the worm, driving the worm-wheel keyed on the beam shaft, is supported by the frame.

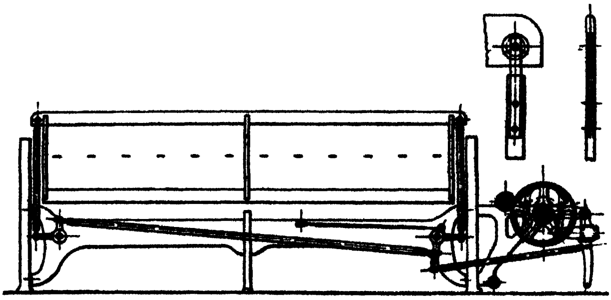

FIG. 9—Mechanism of positive shaft movement from below (Saurer).

The let-off motion must increase, when the diameter of the warp beam has become smaller. This is secured in a very similar way. The rod, 17, makes a to-and-fro movement of constant length and the tappet roller, 10, carries the ratchet lever, 11, through an angle, which increases when the axis of the ratchet wheel is raised. The let-off motion is further influenced by the warp tension; the lost motion between the tappet, 10, and the ratchet lever, 11, decreases with increasing warp tension. This beam stand is quite independent of the loom and can be erected at a distance from the loom, to suit the quality of the yarn to be woven.

The taking-up motion has to deal with very similar problems. The accuracy asked for by the work done makes milled gears, worms, worm-wheels, etc. imperative. Modern designs make it possible to adjust the taking-up to suit any

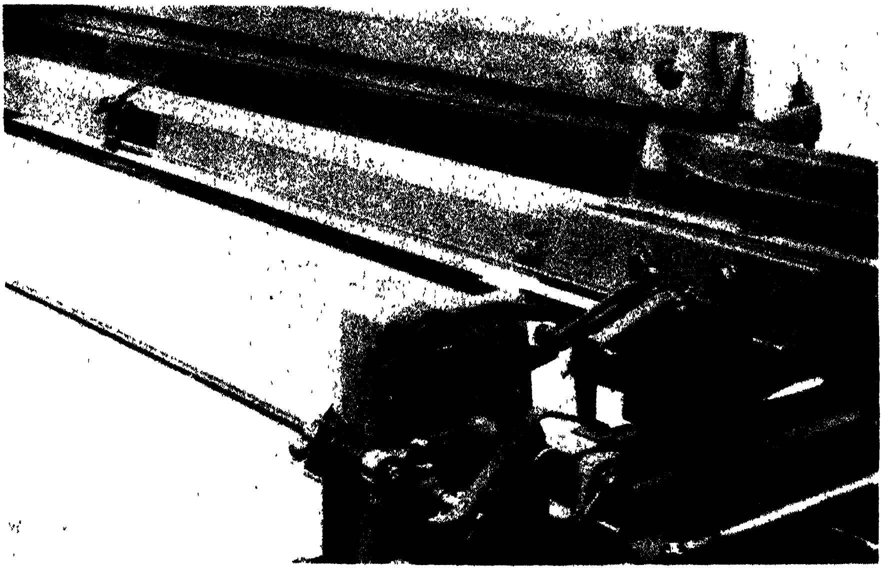

FIG. 10—Central weft stop motion (Benninger). (See also Fig 11.)

practicable number of picks-per-inch without changing wheels. The direct taking-up motion, mostly adopted for silk and rayon, has to consider the increasing diameter of the cloth beam. The ratchet wheel casing of the taking-up motion shown in Fig. 6 (A and B) is divided by a plane perpendicular to the axis. Both ratchet wheels have 30 teeth, whilst, of the two halves of the casing, one contains 31 pawls, and the other 31 detents. The first half-casing rocks to-and-fro through an adjustable angle, being acted upon by a cam wheel on the crankshaft, through a connecting rod and levers. The second half-casing is fixed. The ratchet wheel is driven forward by the pawls in the rocking casing, the smallest possible movement being equal to 1/30th of one tooth, and is prevented from moving backwards by the detents in the fixed part of the casing. The movement is transmitted to the cloth beam by gears and worm and worm-wheels. The movement can be adjusted within very wide limits by altering the position of the driver connecting the bent lever at the bottom with the lever of the movable casing. On the other hand the taking-up motion, which is directly transmitted to the cloth beam, must consider the diameter of this beam. For this purpose a feeler-roller resting on the cloth beam is connected with the sliding block, receiving movement from the cam wheel on the crankshaft, and pulls it gradually up, as the cloth beam diameter increases. The angle of vibration of the bent lever becomes accordingly smaller.

An entirely different design of taking-up motion is shown in Fig. 7. A steadily-revolving shaft at the back periodically, once every pick, through a Maltese cross, turns a hollow shaft through 90°. From this hollow shaft the movement is transmitted by the countershaft above to the concentric shaft leading to the sand beam or to the cloth beam. The speed reduction can be adjusted very widely by the two sliding keys in the gears of the top shaft.

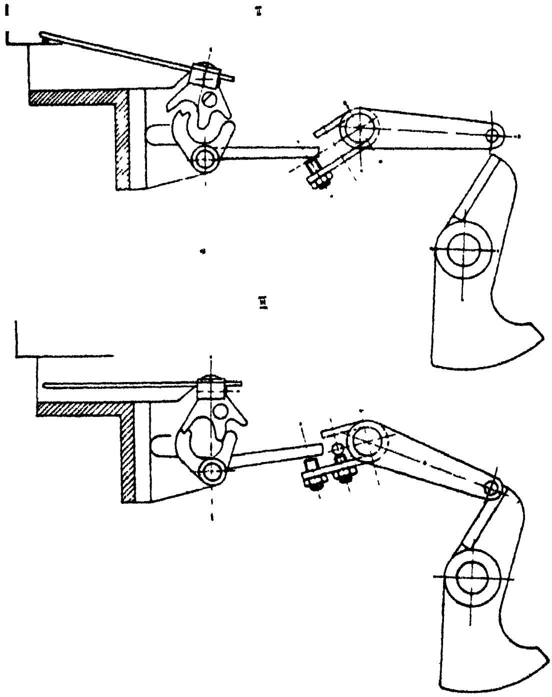

FIG. 11—Mechanism of weft stop motion.
Top—Nib's movement arrested by weft.
Bottom—Weft broken, loom will be stopped.

SHEDDING

Little need be said about shedding, which is done on silk looms in very much the same way as on other looms, excepting the fact that the depth of the shed is smaller.

The healds must be suited to deal with so delicate a warp and they must be as fine as possible, considering the great number of warp threads-per-inch often encountered. Fine twine healds are often used, but mostly special wire healds are given the preference. Inside treading motions are used for plain fabrics, but instead of the top bowls generally adopted on cotton looms, conical cord rollers, are in general use. Dobbies for silk looms are of lighter design and more accurate workmanship, than ordinary dobbies; the same remark holds true for Jacquard machines. In both cases double lifting arrangements are in general use.

A special loom design, in which the shafts are positively driven from below, has no strings, cords, or top bowls encumbering the space over the loom. The advantage of this arrangement becomes particularly apparent, when no dobby is needed or when the dobby is attached on the side of the loom frame. See Fig. 8.

The shedding mechanism is illustrated in Fig. 9, which also shows the expedient way of holding the shafts between two springs; each individual shaft can easily be inserted into the loom or removed from it.

PICKING MOTION

The under-pick motion is generally adopted now for silk looms and has nearly supplanted the over-pick; the preference is given to the under-pick, because the over-pick may occasionally soil the fabric. Particular attention is given to the pick, which ought to be soft, free from shocks, and accelerating the shuttle in a steady and quiet manner. This is necessary to obtain a high-quality fabric, and by the way this will improve the operation of the loom generally and will reduce the wear of all parts connected with the pick. To improve the shuttle race, certain loom makers dispose the shuttle box swell on the front side, thus getting an uninterrupted straight guide for the shuttle on the back side. A successive reduction of the speed of the arriving shuttle is also of importance and will be attained by a good design of the swell. The swell, after stopping the shuttle, will hold it fast until the next pick; a tappet on the crankshaft or a rod attached to the crank arm releases the shuttle soon enough, to prevent any injurious friction when the shuttle is accelerated for the next picking motion.

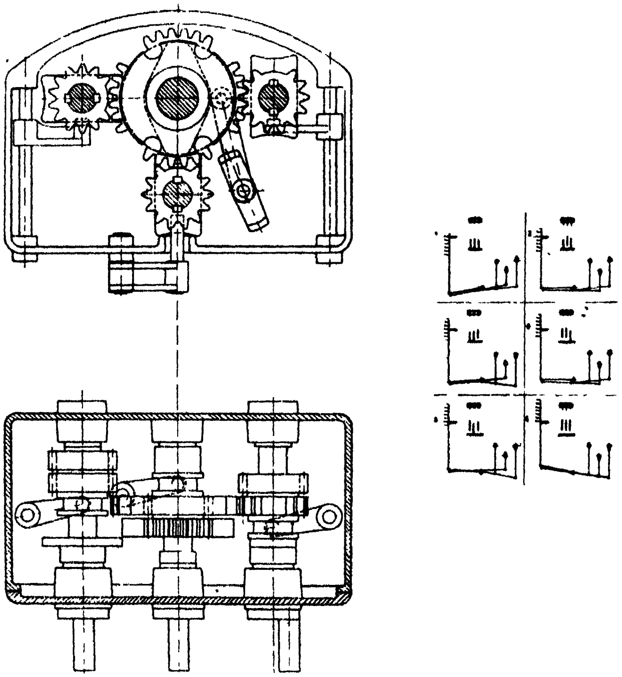

Fig. 12—Gear arrangement for change mechanism. Sketch of the six different positions of change box.

Up to the present boxwood shuttles are most generally used and are often provided with a thread tension regulator or with pieces of fur, having a similar influence. In this connection some words may be added on the weft-stop motion. The well-known weft-fork motion is sometimes used, but as a rule, a weft-stop motion acting in the middle of the cloth is given the preference, as it works more readily; in case of weft breakage the loom is stopped so quickly, that the slay will stand still when the reed is about 1 inch distant from the beating-up position; consequently the broken weft can be removed at once, without loss of time. The structure of such a weft stop motion is shown in Figs. 10 and 11, which are self-explanatory. It is worth notice that all adjustable parts of the stop motion are disposed on the side of the loom and are easily accessible.

It is important, for obvious reasons, for the central weft-stop motion that the nib should touch the weft thread whilst this is still kept stretched by the shuttle and that the pressure exercised by the nib on the thread should be very small. A special design aiming at a particularly light touch of the thread is described in Figs. 10 and 11. After the shuttle has passed the middle of the slay, the nib is given an impulse to fall and is immediately left free. If it meets the weft, as it usually will, it will only press on this with a force corresponding to the kinetic energy of its own small mass. If the weft is not in the nib's way, the nib will

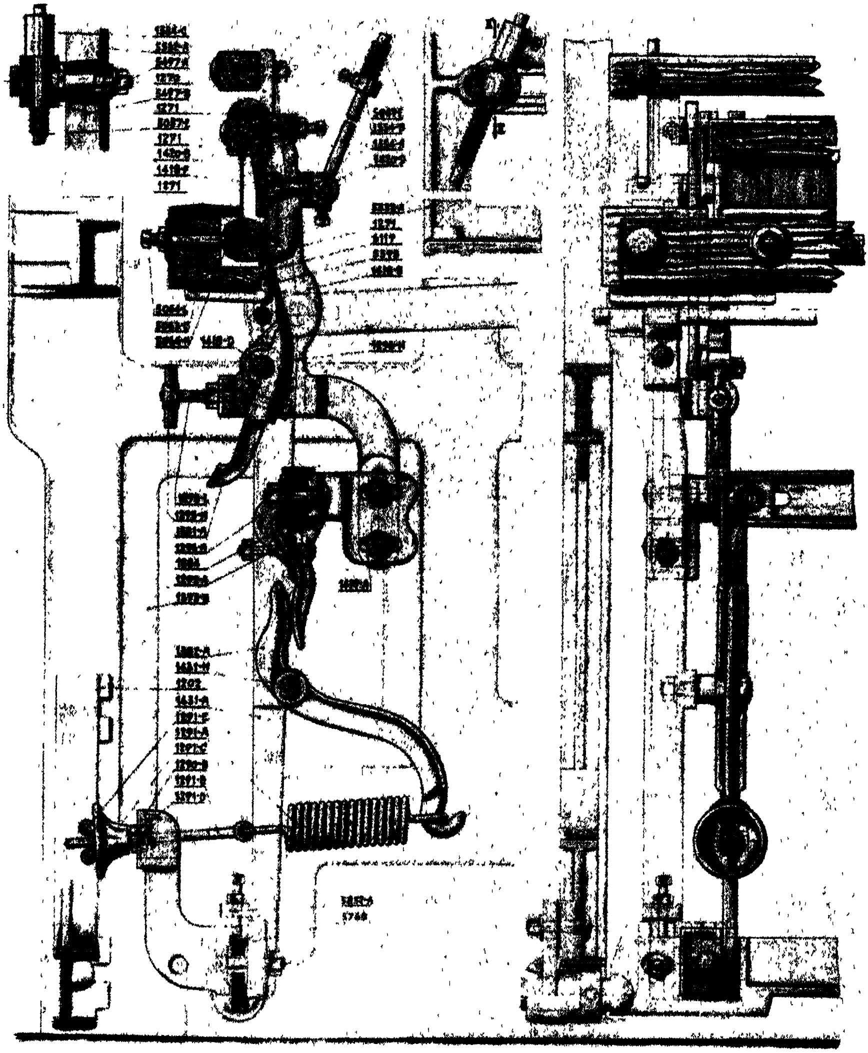

FIG. 13—Mechanism of inclined reed motion (Jaeggli).

go on freely to its lowest position and at once cause the loom to be stopped, preventing the backward movement of the weft-stop motion shaft.

Though the majority of silk looms are working with one or two shuttles (crêpe looms), 4- and 6-shuttles change looms, as well as pick-and-pick looms, are used to a considerable extent. Without going into a description of the different types, a few remarks about a 6-shuttle change box may be added. Fig. 12 explains the mechanism and the six different positions of the change box. The position of each one of the three cranks can be altered by making its gear gear with the central segment gear. These changes may be governed by the dobby or a special cam chain.

BEATING UP

On silk looms, the reed is only 3 to 4 inches high and the wires of the reed are particularly fine; in extreme cases the wires are made of brass and their pitch may be as little as 0·01 inch.

The blow of the slay ought to be light and always the same. To a certain extent, the first condition is satisfied by the lightness of the whole loom and particularly of the slay, by the reduced length of the to-and-fro movement of the slay and by the small proportion of the crank radius to the crank arm. As mentioned before, uniformity of beating-up reaches a high degree if individual drive is used. In this case, the first beating-up after starting the loom, deserves particular attention. Most silk loom makers keep the motor and the main gear continually running and start the loom by engaging a friction coupling The acceleration of the loom is particularly high in this case, the motor having not to be accelerated and its kinetic energy being available.

But the precautions mentioned, though indispensable, are insufficient, when making very fine fabrics, especially crêpe-de-chines, or fabrics containing weft threads of different counts. In such cases, the quality of the weaving can be much improved if an inclined elastic reed is used. At the moment of beating-up, the reed leaves its approximately vertical position and becomes inclined, so that the force exercised on the last weft thread and on the fabric is not purely horizontal, but has also a vertical component. As through the action of this force the fabric and warp can bend slightly, practically without increase in the warp tension and with a constantly horizontal beating-up force, the inclined reed will give a very light and perfectly uniform beat-up. Even different weft yarns will weave correctly with a negative take-up motion. Fig. 13 shows a design of inclined reed motion; the pivots, round which the reed may be turned to take up the inclined position, are not rigidly fixed on the slay, but are kept in vertical levers, which themselves can pivot round a horizontal axis. Powerful springs at the bottom keep these levers in the correct position and press the reed forward. Even in a vertical position, this reed would give a soft beat-up. Moreover the reed can be inclined when the slay approaches its forward dead centre.

WHAT ARE THE PROSPECTS OF AUTOMATIC LOOMS IN THE SILK INDUSTRY?

Before considering the above question, some remarks about warp-stop motions for silk looms may be inserted, a problem interesting in itself and closely connected with automatic looms.

Warp-stop motions are particularly useful for yarns of fine count, which will naturally show the greatest number of broken ends. On the other hand, fine yarns are more liable to be damaged by the warp-stop motion, if an ordinary design is used. Moreover, the application of warp-stop motion to fine yarn warps is rendered more difficult by the fact that the number of warp threads is usually exceedingly great. Attempts have been made to apply to silk looms the well-known warp-stop motion with detectors, hanging on the threads; the droppers have to be made of particularly thin steel sheet, for the two reasons just mentioned. Considering the delicacy of the droppers themselves, electric contact rails have been used in some instances instead of vibrating combs or similar mechanical

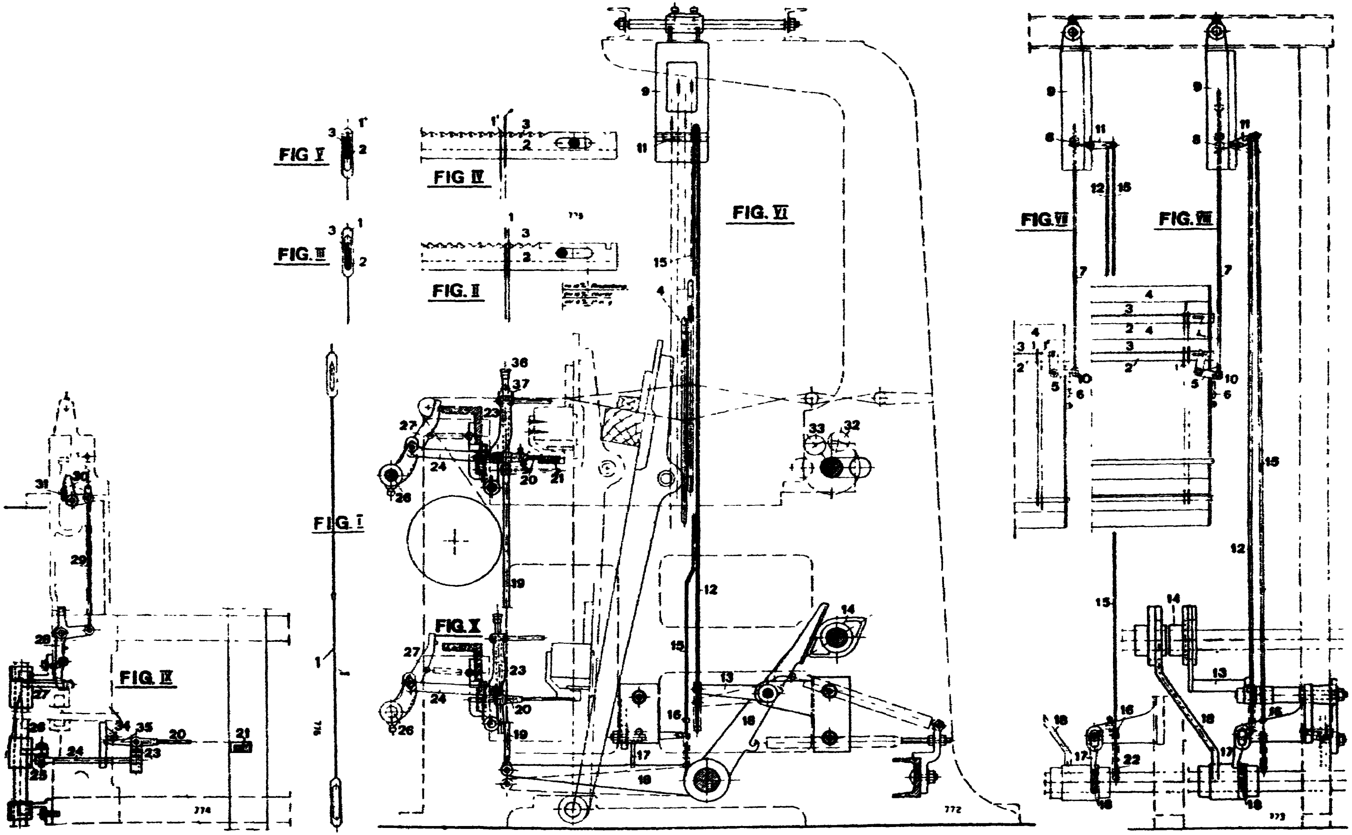

FIG. 14—Harness with warp stop motion, purely mechanical (Ruti). 1' heald low, warp thread broken; accordingly, sliding movement of vibrating comb 2 will be stopped; 11, 15, 16 will not go to their lowest position; 17 will prevent 18, 19, 20 from moving to highest position; 21, attached to slay, meeting 20, will stop the loom.

devices. Many loom makers, however, refuse to adopt a warp-stop motion which necessitates a new point of touch of the threads. Because the friction there produced, though it be small, will increase the number of broken ends. Of late, new designs have been successfully developed, combining the warp-stop motion with the harness. The contact, which cannot be escaped anyhow, between the warp threads and the healds, is made use of to detect broken ends. Various independent designs have proved thoroughly efficient, some of which are electric, others purely mechanical. In Fig. 14 a purely mechanical method is shown. Assuming one end to be broken, the corresponding heald will not be pulled up by the thread when the stay moves to the lowest position, but will fall by its own weight. The top end of this heald will prevent the vibrating combs from moving to-and-fro and will cause the loom to stop. The electric warp-stop motions of the same principle work in exactly the same way, except that a dropped heald due to a broken end does not hinder a mechanical movement, but makes an electric contact, which will, again, cause the loom to be stopped. It is obvious that these warp-stop motions are only applicable when steel wire healds are used.

The effect of the warp-stop motion may be to increase either the number of looms entrusted to one weaver or the efficiency of the loom. The first object is the one usually aimed at; warp-stop motions are, naturally, indispensable on automatic looms. When used on ordinary silk looms, warp-stop motions make it possible to entrust four or six looms to one weaver. At the same time they improve quality and efficiency. If these looms are further provided with a cop-feeler. which will stop the loom shortly before exhaustion of the weft cop, the efficiency will be further increased. On 4-ft.-wide ordinary silk looms running at up to 170 picks per minute, the efficiency may be said to vary from 65 to 85%, the divergence being due to quality differences and local conditions.

As mentioned before,* the change of bobbins in the shuttle is mostly responsible for a very small proportion of the total time lost; a 20-grammes bobbin, titre 50, for instance, will be exhausted in 20 minutes, working on average conditions.

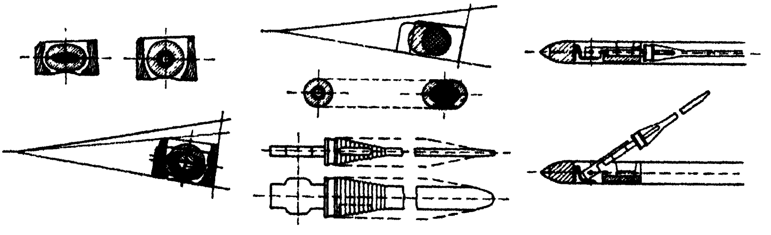

FIG. 15—Flat pirns for shuttles (Ruti) Comparison of flat and round pirns of equal capacity and corresponding shed depths Comparison of flat and round pirns of equal height; difference of section shown black Shape of flat pirn and device to keep it in shuttle.

The main work of a silk weaver consists in supervising the warp and the weaving, whilst weft cop changing is of subordinate importance. Of late, this proportion of the duties of the silk weaver has been considerably altered: further reduction in the time lost on weft changing has been made by a remarkable improvement, which makes it possible to increase the amount of weft yarn in the shuttle to approximately the double, everything else being equal. This important advantage has been obtained by using flat pirns, carrying a double yarn volume, in specially designed flat shuttles. Fig. 15 shows the sections of shuttles for flat and ordinary bobbins of the same capacity and the corresponding opening of the shed in the back position of the slay. It will be seen that the shed can be reduced by one-fifth if flat pirns are used. Keeping the same shed opening, a shuttle of double yarn capacity can be used, if flat pirns are adopted. The very plain and expedient way of fixing the pirns in the shuttle is further illustrated. The winding of the weft pirns does not cause any particular difficulties.

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* Introduction page 116.

The advantages of this improved shuttle design, which can be used on any loom, are self-evident and may be recapitulated as follows—

Very few pirn changes per hour, *i.e.* increased efficiency and lost time reduced.

Keeping the shuttle capacity unaltered, the shed opening can be reduced by 20 to 25%, and, therefore, the number of picks per minute can be increased considerably (for instance, 10 per minute) at the same time reducing the number of broken ends.

In both cases more looms may be entrusted to one operative.

Incidentally, the flat pirns work very well in the shuttle, the weft coming off easily; the danger of several windings being thrown off together has practically disappeared.

The improvements mentioned—warp-stop motion; central weft-stop motion; automatic warp let-off motion; all possibly combined with a shuttle of increased capacity—will make it possible to entrust up to six looms to one operative and to work with high efficiency. A greater number of looms in many cases could not be left to one operative, even if automatic looms were used. Six looms may have 60,000 to 100,000 warp threads, to look after which, will fully occupy one weaver. However, automatic looms may be of advantage when working coarse counts with a correspondingly smaller number of warp threads. It is remarkable that the efficiency limit for automatic looms is approximately equal in cotton and silk weaving. Finer yarns than 50s to 60s counts in cotton, or deniers of 100 to 120 in silk will not work well on automatic looms. With coarser yarn the automatic loom is firmly established in the cotton trade and may be of advantage also in the silk and rayon industries.

A shuttle-changing system recently developed for automatic silk looms will be described. Compared with pirn-changing, the following advantages are claimed for the shuttle-changing system—In weaving silk or rayon, particular care must be taken to retard the weft thread in the shuttle as required by the type of fabric being woven. It is important to regulate the brake in the shuttle accordingly,

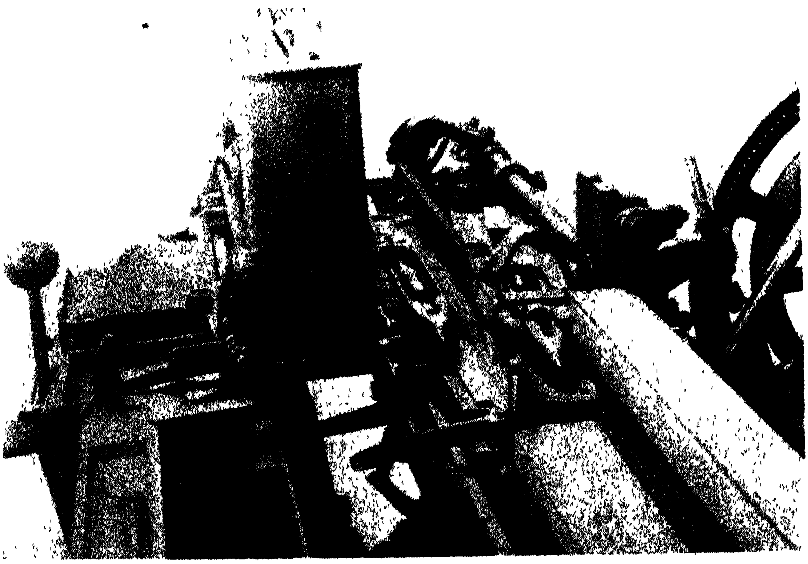

Fig. 16—Full shuttle being pushed into shuttle box, empty shuttle visible behind switch.

which is hardly possible, in automatic pirn-changing shuttles. Moreover, with the shuttle-changing system there is no danger of damaging the weft during the change, and any types of bobbins may be used.

The automatic loom in question changes the shuttle without speed reduction, at the same time avoiding any increased wear of the shuttles. A weft feeler is disposed on the right-hand side of the loom, consisting of a needle, which enters a slot in the weft pirn when the pirn is nearly empty. When arriving on the other side the exhausted shuttle will not enter the shuttle box, but will be slightly diverted by a switch placed in its way. The angle of deviation being very small, the shuttle will not endure the action of much force. Simultaneously, a full shuttle will be dropped from a magazine holding 2 × 7 shuttles, and pushed gently into the shuttle box from the front side, whilst the slay is beating up and the switch is moving back to its usual position, Fig. 16. As soon as the new shuttle is in the right place, the shuttle box, which had to be raised for the change, will be lowered again. The exhausted shuttle falls down a wide curved guide and will remain in a suitable box at the bottom.

RIBBON AND SMALLWARE LOOMS

Ribbon weaving is so important in the silk and rayon industries that a few remarks about it seem justified, so much more so, as noteworthy new designs have been brought out lately.

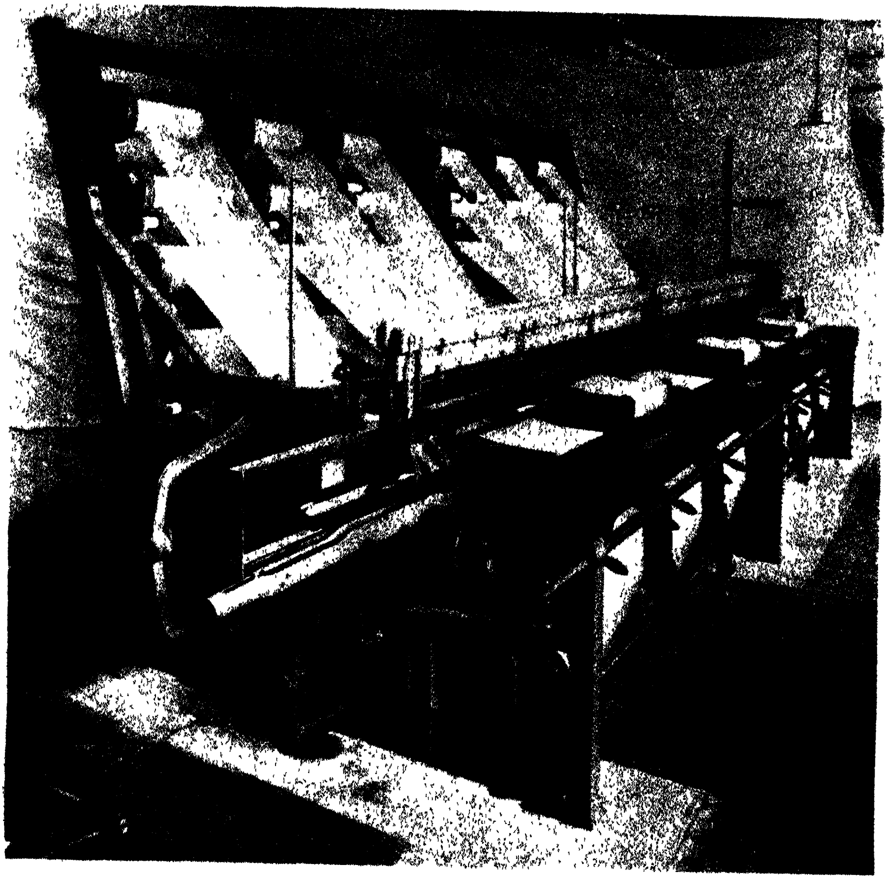

FIG. 17—**Multi-shuttle smallware** loom (Saurer); gear for positive shuttle motion visible in front.

In the section on "Shedding", a multi-shuttle ribbon loom was referred to, with outside tappet shedding-motion acting from below on the shafts. The batten carries two rows of shuttles, which are positively moved from a broad gear on the left side of the loom as shown also on the smallware loom in Fig. 17, over which broad gear the batten moves backwards and forwards, without ever getting its rack out of gear. A very similar loom, suited to weave ribbons up

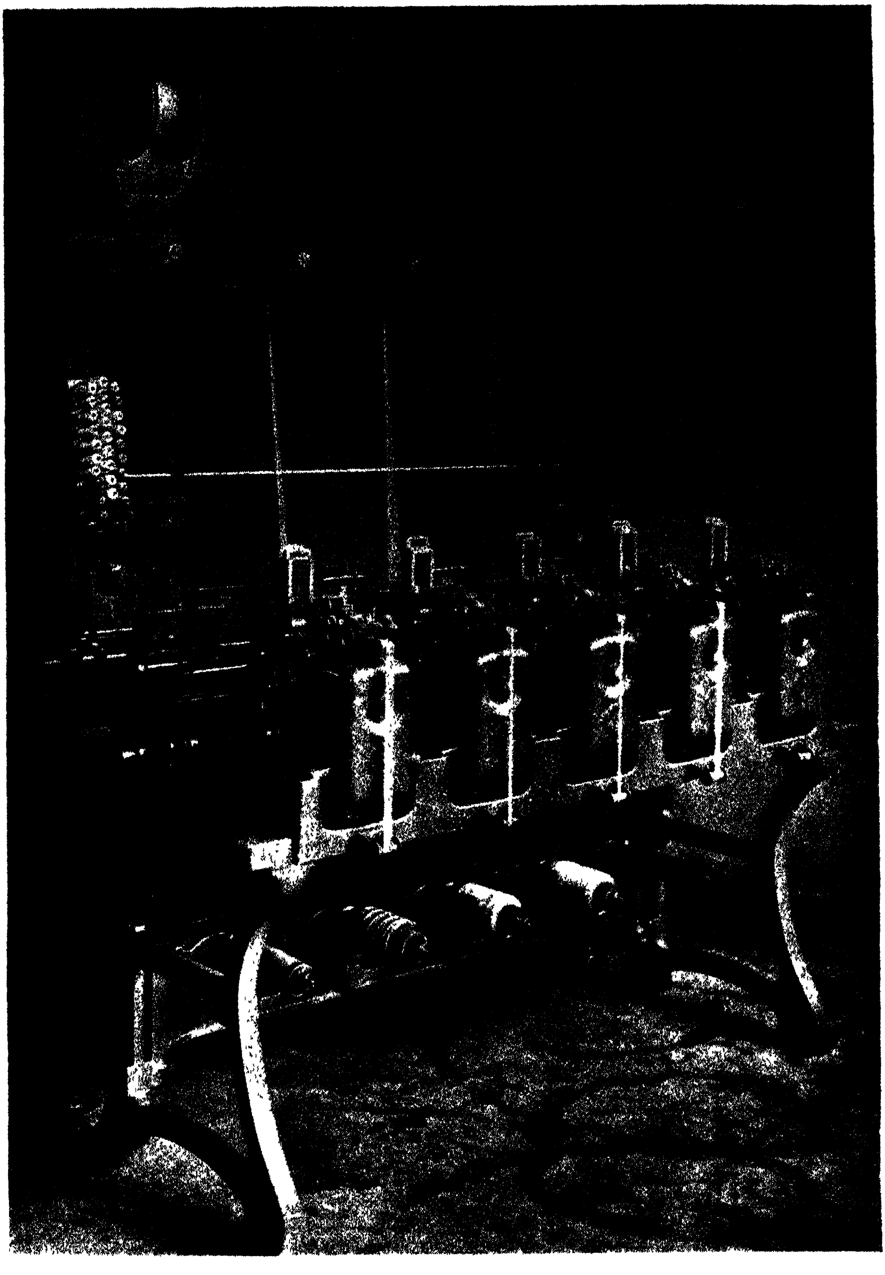

FIG. 18—Group of five high-speed single shuttle ribbon looms (Saurer). Rubber attachment on first loom; tinsel woven on last loom. See also 19*a* and 19*b*.

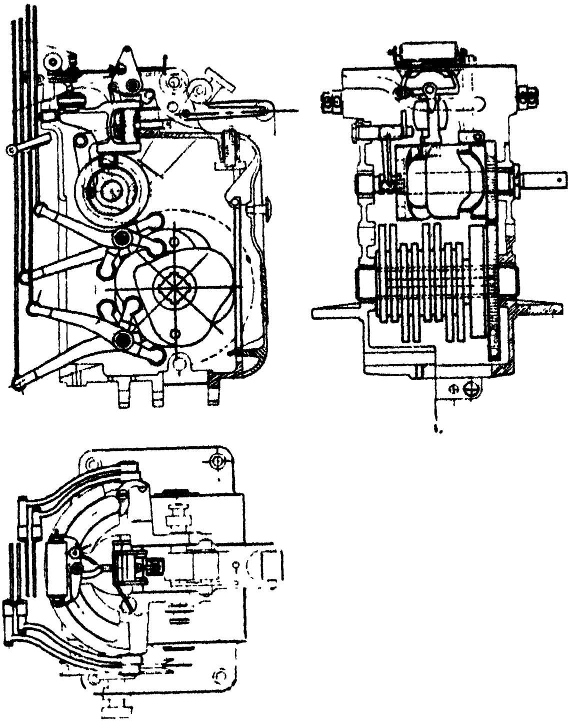

FIG. 19a

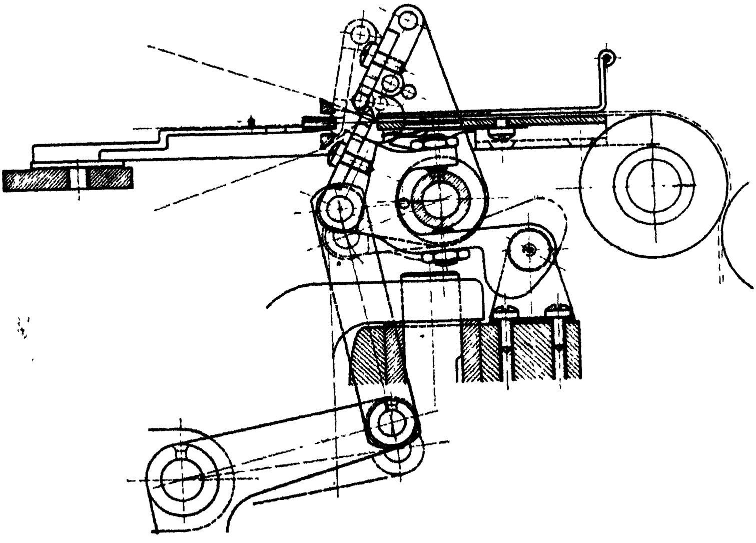

FIG. 19b

FIG. 19—Construction of high-speed single shuttle ribbon loom. (*a*) Shedding and picking motions. (*b*) Split reed.

to 6 inches wide, is fitted simultaneously with a dobby and taffeta apparatus; as the loom is designed to use up to 32 shafts a very great variety of patterns can be made on it. The smallware loom, shown from the driving side in Fig. 17, is also designed according to the same principles and has the same advantages. The width of the ribbon woven can measure up to 16 inches.

Owing to perfection of design and workmanship, these looms can make from 60 picks per minute, for 16-inch-wide ribbons, up to 200 picks per minute for ½-inch-wide ribbons, and still work smoothly. At these speeds, which may be considered as records for multi-shuttle ribbon looms, the efficiency may vary from 70 to 80%. The principle of operation of these looms is such that higher velocities seem excluded.

Much higher velocities have been realised, however, on the high-speed single-shuttle ribbon loom, shown in Figs. 18 and 19 (A and B), which is working on perfectly new principles. The width limit has been raised of late from ¾ inch to 1½ inches; the loom is running at up to 700 picks per minute. Though five or more looms are combined to one group for the sake of space economy, every little loom is perfectly independent and all parts are easily accessible. The warp tension suited to the yarn woven is kept constant by an accurately proportioned brake drum.

The original design of the loom is shown in Figs. 18 and 19 (A and B). The four shafts are positively driven by four double eccentrics and oscillate around a common axis coinciding with the pick line, thus reducing the warp yarn friction in the heddles eyes to a minimum. The shuttle, positively driven as well, is guided in a semi-circular horizontal line. The correct length of weft is pulled off the shuttle at every pick, and is laid behind the reed. The split reed consists of two rows of teeth arranged one above the other, which separate, at each pick, in order to allow the weft to pass through to the front side of the reed. Immediately afterwards the top and bottom reeds close again and beat up the weft. The reed motion is very small and causes very little friction on the warp. The number of picks can be varied through change gears between 7 and 250 picks per inch.

As large weft bobbins can be used and broken ends are seldom, owing to the fact that the warp undergoes little friction and is submitted to a known tension, the efficiency of the loom is very high—from 80 to 90%. The great production of this type of ribbon loom is due, first of all, to the high speed, but to a certain extent also to the good efficiency and to the great length of the warp. One operative may attend on 20 to 40 looms.

All ribbon looms described have the one quality in common that they are suited to weave all kinds of yarns—silk and rayon, but also cotton and other yarns, tinsel, rubber, etc. This is due to their theoretically correct design on the one side, to their great adjustability on the other side.

Great assistance and help was granted to the author, whilst writing this paper, by the following Swiss loom makers—Etablissements Benninger, S.A., Uzwil; Jakob Jaeggli & Cie, Winterthur; Ateliers de Construction Rüti, Rüti-Zürich; Société Anonyme Adolphe Saurer, Arbon; to whom he wishes to express his best thanks.

A BRIEF SURVEY OF CARPET MANUFACTURE WITH SPECIAL REFERENCE TO THE MAJOR INVENTIONS AND NOTES ON CHANGES IN DESIGN

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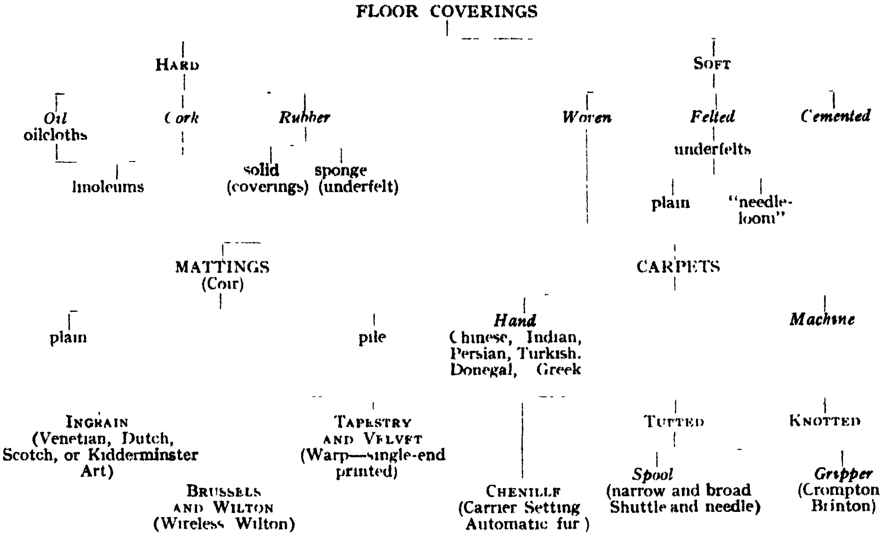
INTRODUCTION AND GENERAL

The general relationship of the coverings for floors is brought out in the table below. The divisions into hard and soft, etc. are easily followed and the point which requires some explanation is that which comes under the heading of cemented; this will be explained later.


FLOOR COVERINGS
HARD
SOFT
Oil
oilcloths
linoleums
Cork
Rubber
solid (coverings)
sponge (underfelt)
Woven
Felted
underfelts
plain
"needle-loom"
Cemented
MATTINGS (Coir)
plain
pile
CARPETS
Hand
Chinese, Indian, Persian, Turkish. Donegal, Greek
Machine
INGRAIN (Venetian, Dutch, Scotch, or Kidderminster Art)
TAPESTRY AND VELVET (Warp—single-end printed)
BRUSSELS AND WILTON (Wireless Wilton)
CHENILLE (Carrier Setting Automatic fur)
TUFTED
Spool
(narrow and broad Shuttle and needle)
KNOTTED
Gripper
(Crompton Brinton)

In the East carpets were originally used for hangings and covers; they were put on the ground or floor but were not walked on but used to sit or lie on. As they were introduced to the West their use was adapted to that of a floor covering; their introduction to England was by the means of, firstly, direct importation and secondly, gradual percolation from the East, either through the various Continental countries or with the Moors along the North African coast and into Spain and France.

In the main a carpet is characterised by having generally a surface of animal fibre, which is held in place in various manners, usually by yarns of vegetable origin. It is the natural resiliency of wool, etc. which accounts for its almost universal use as a surface material.

The term "carpets" in this country covers piece, or body goods, stairs, squares, and the smaller pieces or rugs; in the U.S.A. the term "rugs" implies all sizes of squares, whilst goods in roll as "body" and "stair" are called carpeting.

The first carpets to be made by machine were the "Ingrains", that is in the sense that the weaving was in a horizontal plane as distinct from the hand-made ones where the weaving is in a vertical plane, though in both processes the loom is used; the horizontal one has the movable reed for beating up the weft—hence it may be implied to be a machine—whereas the beating up in the vertical loom is done by a small sectional comb. Ingrains were made before and after power was introduced, and continued in general use up to about the early years of this century; their pattern is produced through the agency of a Jacquard for the control of generally three colours in warp and weft, which in some types gives a double or treble-ply structure, which may, or may not, be strictly reversible. There is no surface to the carpet other than the warp and wefts which constitute the pattern.

Brussels and Wilton, the next in historical order, are again a Jacquard-controlled fabric but, in this case, it is only the warp which is brought to the surface to produce the pattern; if this is left in the form of loops the carpet is a "Brussels" while if cut to give a velvet effect a "Wilton" is the result. In both cases there is a general maximum of five colours or frames of yarn, and those other than the one being shown on the face lie buried in the back. On the Continent the Wilton is known as Tournai.

Tapestry and tapestry velvet can be considered as a one-frame Brussels or Wilton; the pattern is obtained by printing the warp ends individually and setting or aligning these in numerical sequence, and at the same time placing on beams for weaving. The name may be considered as having been derived, owing to its similarity to tapestry, *e.g.* gobelins where the pattern is given by inserting small lengths of coloured yarn weft-way by needles; in both cases all the design giving yarn is on the surface.

Chenille similarly to tapestry entails two processes. The weft or fur is first woven using several coloured wefts with a fine warp, the ends of which are grouped in a very coarse pitch. This cloth is then split or cut between the warp groups to give the long lengths of fur. (Chenille—French—denotes hairy caterpillar.) In the setting loom this fur is attached to the backing to form the carpet.

Tufted carpets are produced by inserting each weft-way line of pile at a time by either of two methods. In the first, or older, way all the yarn for each line of pile is wound on a long bobbin or spool; these are assembled in numerical order on a long chain and are removed therefrom individually when the ends are placed in the carpet; the requisite length is drawn-off and cut and the spool returned to the chain. In the second method, a Jacquard controls the yarn and the coloured ends required are placed in line; a row of nippers or grippers takes hold of the ends and draws off the length of a tuft; the yarns are cut and the grippers deliver them to the fell of the cloth.

The knotted carpets, whether hand or machine-made, are characterised by the pile being twisted round the warp; the three types of knotting are the Chinese, Persian or Smyrna, and Turkish or Ghiodes, where in the two latter, two adjacent ends are used. Generally the machines are for tieing the latter two and the main principle used is to shrog or move the warps laterally during the process.

It is interesting to note how the names such as Chenille, Axminster, Moquette, were originated. In the Templeton (8169) patent of 1839 the cut V-fur is to be "used as weft somewhat in the manner to Chenille weft"; from this one infers that round fur was known previously for chenille fabrics and hence chenille carpets, but again Templeton (12954/1850) concerning chenille weft, states its use for Axminster carpets; thus the name for a machine-made fabric became added to that of a hand-made one. Also Crompton, in patent 1634 of 1881, states that "a tufted fabric if a carpet will be of the class denominated moquette wherein the separate tufts composing the fabric are locked about a tufting weft instead of about the warp as in Axminster carpets". This confirms that Axminster was a hand-made cloth; Smith (24455/1894) also confirms this definition of moquette. Grosvenor (7805/1902) mentions moquette or tufted Axminster whilst Parmentier (17744/1905) definitely states moquette to be a double plush structure; this is generally what the word implies at the present time. Thus it is evident that two separate and distinct structures are implied by the word moquette.

Over a very long period, suggestions have been put forward for attaching or cementing fibre, without spinning, to a backing. This of course eliminates the weaving of carpets though it entails the preparation, generally by weaving, of the backing. Within the last decade, at least one method of cementing has been brought to large-scale production; during the same period semi-cementing processes have been perfected, *e.g.* a very loosely-woven pile fabric has all its constituent parts consolidated by an easily applied cementing agent. Both these processes have been helped considerably by the use of "latex" rubber—which is the natural exudation from the rubber tree—somewhat concentrated and applied as an aqueous emulsion together with vulcanising agents. After application and even moderate heat treatment the rubber is cured. Previously the rubber was evaporated after collection and in order to prepare it for application had to be purified and dissolved in some organic solvent (highly inflammable); thus it can be appreciated how much easier is the application of rubber by the "latex" than by the "solvent" method.

When the weaving process is complete, there is still that of finishing. Mainly this consists of steaming the face (if a velvet surface—which causes the release of the stresses imposed on the fibres during spinning, and so gives better cover); the application of a sizing mixture to the back to give additional stiffness and wearing properties; drying to remove the condensed moisture from the steaming and the size; burling or mending; brushing, cropping, or shearing to reduce the pile to the correct levelness, and finally the cutting up and sewing-over of the ends in the case of squares and rugs or the sewing together of strips of body to give for example a fitted carpet.

There are two methods of finishing, however, which may be briefly noted; both are wet processes and have for their object similar results but are used on different types of carpet. The first is the washing of orientals. In the beginning these carpets were dyed by the use of generally fast natural colouring matters, and in the course of use, owing to some being somewhat faster than others, there was slight altering of general tone as well as a mellowing and polishing of the surface. When the first synthetic (basic) dyes were invented they were quite fugitive and were introduced to the Near East. Consequently some carpets when imported would contain yarn dyed with both fast and fugitive colouring matters and the washing process was used to discover the fugitive portions which had to be replaced. This treatment was developed to give the polish and lustre possessed by the older and used carpets to the newly-made ones. The second method, though a development of the first, takes machine-made Wiltons which have been dyed with Chrome Mordant (synthetic) dyes and subjects them to a full chlorination treatment which produces a lustre or sheen. In the U.S.A. the market for this type is pronounced though it does not appear yet to have been offered in England.

The amount of honest hard wear a carpet will give depends naturally and primarily on the quality; as there is no generally applied test the ruling of manufacturers and distributors is generally accepted in lieu thereof. Some motor car manufacturers have given the matter their attention, particularly as there is very hard wear at the place of the driver's heels, when seated at the controls. A well-thought-out piece of apparatus has been described by the inventor (Ashcroft, *Melliand Text. Monthly*, Vol. 4) where the piece under test is fixed on a circular table and is frictionally driven by a leather-covered roller; the carpet in turn drives another leather-covered roller which is retarded by a brake. The depth or thickness is measured before test and after various numbers of revolutions of the first roller. From these figures, if graphed, it can be seen how much of the loss is due to crushing of the pile and to actual wear, hence comparisons made of different qualities. Also it is suggested (Shliefer & Cleveland in *Bureau of Standards Journal of Research*, 1934, Vol. 12) that the wear to be given by a carpet is proportional to the square of the density of the pile times its length: they also show the beneficial action of underfelts in prolonging the life of carpets particularly those of poor to medium quality.

Inventions

In the following brief summary of the inventions relating to carpet manufacture, the divisions are those of the various types of carpet; and there is a section on wires used for cutting the warp to produce velvet fabrics as well as shearing machines. Some of the patents cited have not been of permanent value, in the sense that they have been taken up by the industry generally, but have been incorporated to show the trend of development. These are shown by the

number followed by year and patentee. British patents are to be understood unless U.S.A. appears in front when American is quoted. Those marked with an asterisk have not been examined either in full or abridgement form; the lists do not profess to be a complete record.

A—Brussels and Wilton

3046—1807	Bowyer; used Stuffer warp in addition to dead ends.
9329—1842	Wood; Wilton woven (double) face to face.
120—1852	Collier; double shed for Brussels—wire and weft entered simultaneously.
14178—1852	Warden; jute for face in hand looms.
752—1855	Nickels and Hobson; loom turned by hand (handle) and weaver puts in wires.
963—1856	Nickels and Hobson; wire inserted by hand, rest by power.
791—1857	Moxon, Clayton & Fearley; tapet and bowl wire motion with spring point on wire table (on present-day narrow Tapestry looms).
2540—1859	Thomson; jute for face in power loom.
1251—1871	Hodgson & Moxon, wire motion.
2764—1875	Bigelow; wire motion
2569—1881	Hall & Hobson; trough wire motion (on present-day wide tapestry looms).
2088—1883	Fawcett; Childema method square weaving.
3169—1883	Brady; paper yarns.
1451—1885	Fawcett; hair and cotton for face
20987—1893	Humphries; seven colours in a five-frame by planting.
2293—1897	Barclay & Craig; wire motion
3905—1901	Hall, counter balanced taffet wire motion (on wide tapy looms). (For hook looms see wires.)

B—Tapestry

6066—1831	Schwabe; yarn from beam block printed on table and rebeamed.
6307—1832	Whytock, yarn on large drums printed by long blocks.
7786—1839	Whytock & Clink—yarn from open reel held by metal clamps to prevent access of colour when dyed.
8811—1841	Henshall; a few ends of yarn from bobbin block printed on table by blocks then hanked and steamed or cloth with few picks printed, steamed, picks removed and beamed.
11643—1847	Morton; colour (thickened) on boards and yarn pressed on to this.
12167—1848	Wood; woven white and printed by rollers
12388—1848	Curtain very similar to latter part of 8811—1841
12954—1850	Templeton used drums and blocks for printing Chenille weft or the fur.
12980—1850	*Cochran; colour put on band and transferred to material
13267—1850	Crossley, Collier, & Hudson; pulley in colour, felt-covered, pawl and ratchet, doctors on pulley and scrapers acting on yarn.
13834—1851	Whytock; transfers colour from roller in box to yarn by pulley in contact with both.
13841—1851	Wood; warps pressed into colours in boxes of required width and starch removed by beating.
1568—1853	Sievier; double width blocks for double woven fabric
2654—1853	Ronald; external heat to steaming chamber (previously only steam into it), i e. cavity wall steam heated.
2694—1853	Potter & Mills; printing cylinder or drum to correspond in length to take up in carpet.
1256—1855	Whytock; similar to 13834—1851 but top pulley revolved causing lower one to turn and yarn between the two.
1116—1856	Whytock; for use with two pulleys yarn tensioned between two cylinders held apart by rods to obviate use of drums.
1954—1859	Hebblethwaite, Shuttlewoth & Tasker; various improvements on drums—brake and knock-off motion.
1474—1860	Widnell; warps printed on table with different blocks; yarn layed on strips of metal or glass instead of chopped straw.
189—1861	Henderson; surface under yarn to be soft and colour box pulley on springs.
2390—1861	Bright (Thomas) & Mills; scraping and evening motion oscillating into action on each side of colour pulley.
210—1866	Stringer & Birch; spacer for yarns on drums.
1591—1869	Crossley & Hanson; steam regulating valve using mercury.
2386—1870	Turner (void through no final specification); concave surfaced pulleys and V-shaped spreaders.

C—Wires

12937—1850	Wood; groove along top and knife along this—also a trough motion.
3907—1888 12450—1892 21786—1892	Segschneider; removable blades.
22571—1892	Stone; removable blades.
26271—1893	Ford; removable blades.
15868—1901	McCollum; wires with wood and knives cut along this.
190644—1922	Gillette; loose knives.
212443—1924	Behrman; loose blades
220565—1924	Lox; seal loose knives.
235718—1925	Gillette; loose knives.
242945 1925	Twigg; loose knives.
263068—1926	Fahey & Wood (Gillette); loose knives.
267099—1927	Schlemper; loose blades.
287340—1928	Pfeiffer; loose knives.
296348—1928	Schlemper; loose knives
375093—1931	Showell & Webb; holder.
394769—1932	Showell & Webb; holder.

All the above are for wires inserted from a side motion under the pile warp ends; in the hook principal the wires with a hook at the end—same number as warp ends—are mounted at the fell of the cloth and advance as a whole into the shed of face yarn. After twisting the face warp is lowered and hence is placed over the wires which have mounted on their shanks small renewable knives; these cut the yarn when the advance is made because the pile is woven in and held stationary in the cloth.

175450—1922 189644—1922	Grosvenor & Picking; hook loom.
205130—1923	Sandeman; hook loom.
255200—1926	Crabtree; oscillating motion.
273059—1927	Oldroyd & Felton; hooks for deep pile.
282294—1927	Britton; hook loom
287952—1928	Grosvenor & Picking; hook loom.
295129—1928 313103—1929	Crabtree; hooks and reed.

D—Chenille

8169—1839	Templeton & Quagley; fur woven with leno in manner to make on splitting the ends come together in V-shape "used as weft somewhat in manner of Chenille weft".
12954—1850	Templeton; weft cylinder or drum printed or plain fur and then split.
816—1855	Templeton; V-fur woven warp way.
905—1855	Templeton & Orr; double-faced Chenille.
2789—1856	Orr; similar to 816—1855.
2237—1859	Lemaire; cutting between wires placed each side of lino in fur weaving.
1041—1861	Templeton; warp Chenille.
4150—1876	Tompkinson & Adam; triple shed for hand setting looms.
5378—1881	Talbot; jacquard presented dyed weft pulled into shed by arms.
1141—1885	Lyle; reversible Chenille of different patterns on each side.
27810—1913 27811—1913	Bond Worth & Rogers; Chenille (setting) carrier loom.
175630—1922	Dietrich; jacquard controlled yarn holders for fur.
213369—1924	Spark & Crabtree; carrier loom.
227582—1925	Crabtree; carrier loom
275703—1927	Champion; selvedge fur, looped round wire.
287365—1928	Kreigl; round fur by corkscrew doubling, cutting, and rebinding.
334626—1930	Morton; jacquard smallware (swivel) loom using wire motion.
334463—1930	Staub; thick yarn on thin core for smooth Chenille.
346047—1930	Fitzpatrick; knitting with long needle with knife on shank.
351404—1930	Morton; tufts supplied by gripper from jacquard controllled yarn and sewn on to core.
352643—1930	Koch; stuffer warps in Chenille fur weaving.
354402—1930	Pozar; Chenille to show on back.
363731—1930	Morton; yarn from jacquard and gripper placed across rubber-coated threads.

	375371—1931	Morton; Chenille formed with hooks and shrogged warps.
	375412—1931	
	384592—1931	Horn; Chenille made on braiding machine.
	399330—1932	Tompkinson; selvedge fur looped round wire and cut during weaving.

E—Spool

	11050—1846*	Newton; spools.
	716—1853*	De Roulet; spool loom.
	1701—1854*	Chevron; spool.
	2434—1856	Smith & Skinner (Newton); a shuttle loom and tufts placed round warp.
	1187—1862	Skinner; improvement of 2434.
	2095—1872*	Holdsworth; spool loom.
	2595—1875*	
	235—1877	Smith & Skinner; needle weft insertion tufts round weft but circular knife.
U.S.A.	203663—1878*	Skinner; four shot (or pick) weave.
	4150—1880	Skinner & Tymeson (apparently covers U.S.A. 233290—1880*); rocking blades and needle motion
U.S.A.	9694—1881*	Smith & Skinner; similar 235—1877.
	291—1881	Adam; weft tensioning on needle.
	1634—1881	Crompton; spools inserted from below shed, and improvement on 2095—1872.
U.S.A.	... ... *	Skinner; tufts put in by grippers but woven upside down.
U.S A.	257395—1882*	Skinner; 3-shot weave.
	7313—1885*	Crompton & Wyman; spool and gripper.
	7314—1885*	
	13684—1885*	Skinner; spool and gripper.
	7222—1888*	Skinner; spool and gripper.
U.S.A.	432763—1890*	Skinner ,, 3-shot weave
	5568—1891*	Skinner & Conolly; spool and gripper.
U.S.A	454414—1891*	Wyman; spools worked without removal from chains.
U.S A	543820—1895*	Wyman; looms containing more than one spool in width.
U.S.A	543825—1895*	
U.S.A.	609638—1898*	Tymeson; wide loom.
U.S.A.	654363—1900*	Skinner; wide loom.
U S.A.	677303—1901*	Wyman & Hutchins; wide looms.
U.S.A.	733207—1903*	
U.S.A.	733586—1903*	
	860—1902	Ibbertson; double needles.
	7805—1902	Grosvenor; Moquette weaves.
U.S.A	756001—1904*	Cooper; setting frames.
U.S.A.	791404—1905*	Cooper; 3-shot weave.
U.S.A.	831951— ....*	Cooper; wide looms.
U.S.A.	891147—1908*	
	238916—1924	Platt; 2-needle double insertion loom.
	351654—1930	Platt; 3-needle single insertion loom.
	382064—1931	
	382943—1931	
	389013—1932	Bigelow Stanford; several looms fed from same chain of spools.
	391396—1932	Spiers; tube threading frame.

F—Gripper

7313—1885	Crompton & Wyman; jacquard presentation of yarn from horizontal position and gripper insertion.
7314—1885	
8772—1887	Fawcett; preparation of tufts for grippers.
15680—1890	Brinton & Greenwood; vertical jacquard presentation with grippers.
207050—1923	Tompkinson; grippers from under shed.
	Various gripper motions are cited under heading of machine knotted.

G—Machine Knotted

12543—1886	Siret & Saulimer; Persian knot on vertical placed warps.
8659—1890	Crossley & Siret; Turkish knots.
4260—1891	Yongjohin & Hughes; Turkish knots loom.
7990—1900	Boyer.
15548—1900	Hughes.
23091—1901	Morton; for Donegal loom.
17280—1902	Landenberger; travelling knotter.
5735—1903	Foster; knotted with needles and similar to knitting.

15283—1905	Costikyan; Persian knots.
15901—1906	Renard; special grippers.
12312—1909	Grosvenor; Turkish knot from Axminster spools.
24847—1912	Tompkinson, Adam, & Young; knotted carpet loom.
20321—1914	Boyer; jacquard and vertical warps.
2742—1914	Banyai.
10886—1915 154594—1920	Boyer.
228943—1925	Banyai.
234486—1925	Boyer.
243791—1925	Frederick & Reich; horizontal warps.
243821—1925	Venail; double lacing of knots.
253630—1926	Felton, Wilber & Oldroyd; Turkish knots.
264578—1927 264579—1927	Oldroyd; measuring lengths of yarn.
273057—1927	Felton & Oldroyd; cutting.
293622—1928	Venail; twisting by combs for moving warps
311232—1929	Boyer.
313190—1929	Bond Worth & Walters; Turkish knots on Axminster loom.
320341—1930 322483—1930	Marks.
334868—1930	Oldroyd; grippers and hooks.
342421—1930	Morton & Oldroyd; shrogged grippers.
342813—1930	Morton; yarn lengths from a knitted feed.
360536—1930	Smyrna Automatic; selector arrangements.
371778—1931	Engel; Renard grippers and tufts parallel to warp.
383466—1932	Bigelow Standford; shrogged warps for persian knots.

H—Cemented

7620—1838	Poole; yarn wound on rods, cemented to back and cut along rod.
1152—1854	Lawson; pile stitched to back.
2200—1856	Templeton & Lawson; sewing or cementing Chenille to backing.
1499—1865	American Waterproof Co.; fabric coated with gum and warp pressed into it over wires—on withdrawing may be cut.
964—1866	American Waterproof Co.; Brussels or Tapestry loop formed with weft instead of wire; thin back yarns and whole rubbered and vulcanised.
19612—1908	Mear & Crawshaw; tufts needled on to base fabric
6343—1909	Thorp; similar.
6185—1911 6186—1911	March; fibre frozen in ice partly thawed for attachment to rubber.
198185—1922	Rousseau; stamps knots on to canvas with metal clips.
250981—1926	Duratex; batt of loose fibre needled through hessian and back rubbered.
263249—1926	Walsh; similar only two or three colours of batt used.
295232—1928	Oryx Fabrics batt looped over axially-placed bars on drums and hessian back fixed thereon with rubber and vulcanised, loops tigered out and sheared.
307713—1929	Nevile & Smalley; tufts sewn on to backing.
317434—1929	Oryx Fabrics; horizontal machine, rubbered each side of looped batt on to backing, then split.
333268—1929 336553—1929	Collins and Aikman; pile of fabric (double) attached to rubbered hessian and split, or woven loops attached and split.
347232—1929	Lea Fabrics; insertion of loops of batt in 295232 by movable carriage.
349141—1929	Mechanical Rubber Co.; yarn stitched through hessian and back rubbered.
367364—1929 369643—1930	Collins and Aikman; rubber-backed carpets joined with rubbered tape to make seamless and/or patterned from various coloured pieces.
371817—1931	Stephens (C. & A.); loosely-woven double fabric back coated and vulcanised, cut dyed, and after-chromed.
357212—1930	Dunlop; fibre attached rubber back and then to sponge rubber or to sponge rubber direct as a backing.
390312—1931	Sanford; flimsey back carpet attached by rubber to open mesh leno back.
390393—1931	Synthetic Fur Mills; Chenille laid in card clothing, and transferred to rubber-treated cloth.
394487—1932	Dunlop; backs sprayed and vulcanised to anchor yarn at back or attach to hessian.
400225—1932	Stephens (C. & A.); pile fabrics with rubbered back.
402296—1933	Blumenthal; formation of sponge rubber back on pile fabrics.

I—Shears

1595—1787	Harmer; scissors shears.
2627—1802	Fryer; blades worked as in pair of scissors.
3945—1815	Lewis mentions "ledger blade" but does not claim spirals.
3951—1815	Price; spirally set blade working against a fixed (ledger) one.
	This machine was probably built with 66 in. blade for cropping 60 in. wool cloth.
	About 1885 machines of 120 in. blade were made (12/4) though ones up to 264 in. on blade (27/4) have been built.

Design—Method—Motifs

The unit of width in carpet design and manufacture is the quarter yard—9 in.—or briefly quarter and written as a fraction ¼. Thus stair carpeting of 18 in. width is 2/4; 22½ in. 5/8; 27 in. 3/4, 36 in. (1 yard) 4/4. Body goods, that is patterned cloth without border, are generally made 3/4, 4/4, and 6/4 (54 in.) and self colours or plain bodies are produced as well in 8/4 (72 in.), 10/4 (2½ yards), 12/4 (3 yards), 14/4 (3½ yards) width.

The quality warp-way is shown by stating the splits or dents, as so many per inch or per 1/4 and is called pitch, *e.g.* a piece of body with 8 per inch will have 72 splits per quarter or per 3/4 (27 in.) 216. Weft-way, a combination of picks or shots of weft together with rows of pile (terry, wires, fur, tufts, according to the fabric) is used, *e.g.* in Brussels and Tapestry (round or loop pile) there are two shots of weft for each loop or wire; in Wilton and Tapestry velvet there may be two or three shots for each; in Chenille (hard back) there are generally four shots of weft in the backing for each shot of fur (face weft); in Tufted carpets the weave mostly is three shot (these can be made altogether, or two, and then one or singly).

The design is produced on squared paper as near to natural or life-size as possible so that the effect of the fabric when finished may be judged. As a carpet is a floor-covering the design is placed on the floor and criticised from that view point.

In the cloths produced by the warp, *e.g.* Brussels, Wilton, and Tapestry, the repeat in that direction is more important than in those produced the other way, and *vice versa* with Chenille and Tufted. Taking as an example a "warp-way cloth", the repeat in a 3/4 body design will be designated a full repeat if the figuring requires an equal-sized figure, but a "mirror" image to complete the effect when two widths are placed together. Again when the figure turns over (mirror image) in the single width the design is a half repeat; further subdivision gives a third, quarter, etc. of the width as the repeating unit. Similarly these repeats may not only "wheel" or turn round when they are joined up but may also drop or be pulled down at the joining line in the design. The length of the drop is governed by the length of the total repeat of the design, *e.g.* ½, ⅓.

In weft-way cloths (chenille and tufted) the depth, or length of the repeat, is the more important factor. For example, should the design turn over (mirror image) on itself along the length of the design, the method in the weaving is (*a*) with chenille to reverse the end of the weft and (*b*) with tufted (spool) to reverse the movement of the spool chain. Hence generally in the squares designs the size is altered in width by the addition of 18 in. repeats of warp in the first type and in the length by similar 18 in. repeats of weft in the second type.

The major alteration in the method of square manufacture apart from the design was the Childema invention of Fawcett, patent 2088 of 1883. Previously to this centre portion of the square was made from widths (3/4 of body sewn together and on all sides was sewn the border (2/4 or 5/8) separately woven and mitred at the corners.

With Brussels (loop pile) the effect was good except for the thickness at the mitre, but with Wilton (velvet pile) the shading shown by the cross borders was objectionable. To overcome this, Fawcett wove the side border with portions of the top and bottom borders and a part of the centre in one width (3/4). Similarly the next width was woven with its proportion of top and bottom border at each end of the part of the centre which was repeated and then came the other side bordered part but a mirror image of the first. These strips when sewn together produce a carpet not only without the mitred corners but with the lay of the pile all one way. Childema (derived from the Greek, meaning luxurious) was the name coined for this method. As looms were pefected for the weaving of the 6/4 (1½ yard wide) cloth the squares were woven in halves and sewn down the centre (that is with one seam instead of three or four) and later with wide looms as at present they are generally made seamless, in some types up to 5 yards wide.

The type of design at present in vogue can be called the modernised or modified futurist. This qualification is given because during the last few years the tendency has been away from crudeness both in colouring—from the harsh to the soft—and in the pattern—from the garish (angular) to the broken with small convential foliage—which was characteristic of the futurist when first introduced. The time lag between the invention of any new method and its general use is illustrated by this style though it is somewhat exaggerated as the war period intervened. The cubist or futuristic movement started in art about 1912 yet it was not until about 1923 that carpet catalogues showed these to any large extent.

The decade from 1923 backwards can be called the copyist or reproductionist period. Types of design from countries in the East—Egypt, Japanese, Chinese, Persian—and those of past periods were adapted successively and in the case of those from the Near East, very successfully, particularly in Wilton.

Previously to this, the "verdure" type was popular; as its name implies these designs consisted of foliage and flowers treated semi-conventionally, and were generally "very busy" or well covered. This type was probably a reaction from the highly "conventional" period which reached its height about 1905; its founder was Wm. Morris, who pioneered this treatment of ornament. He produced from his firm at Merton Abbey all manner of fabrics and materials during the last decade of last century; the method of treatment was "flatness" and to obtain that effect the flower or leaf motif was reduced to the level of a small part and was not the motif itself. Voysey and Crane were of this period but developed it on the lines of large effects with a considerable amount of plain ground.

Before the conventional period, namely late Victorian, "French or naturalist styles" held sway. Here the character was "depth of effect" garlands of roses and leafage in natural colours stood out in relief on back grounds of fawn and green.

In the early Victorian times the "geometric style" flourished; its general character was that of somewhat elaborate figures in bright contrasting colours which were further enlivened by the use of black grounds.

Although these various styles have been shown in the historical sequence it must not be inferred that it is only the conventional futuristic type which is seen in catalogues at the present time. Oriental effects—both hand-made and reproductions—conventional and verdure (treated modernly, particularly in regard to colour) are demanded, whilst for some markets even French types are required. Apart from carpets with design there has developed during the last few years a desire for plains; this is no doubt due to the general excellence of modern furnishing fabrics, which, if used in a smallish room with a patterned carpet, give a cramped or enclosed feeling. If the carpets be plain or semi-plain (indistinct marl or moresque)—either fitted to the room or with a contrasting fitting surround—not only can the furniture be shown to full advantage but the full effect of pattern in the curtains and cushions is obtained.

This tendency, however, was hardly shown in a customer-survey of buying reasons which was undertaken in the U.S.A. in 1929 (*Mohawk Rug Retailer*, Feb.-March 1933) when it was shown that 90% bought figured carpets and 96% preferred squares to fitted ones.

Also the main reasons for buying were shown to be 43% beauty; 20% weave; 30% price; and 7% other reasons.

This periodical also contained the sources of wools used at the Mohawk Mills (who manufacture all types of carpets).

	1928	1931
Manchuria	37·1%	29·4%
Argentine	6·23%	25·6%
United Kingdom	11·32%	7·7%
British India	16·50%	8·4%

The carpet industry in the United Kingdom has three main centres, Kidderminster; the West Riding of Yorkshire; and the lowlands of Scotland. There are about 35 concerns and the estimated number of employees in July 1932 was 27,620 (*Ministry of Labour*). Similarly the industry in the States is composed of about the same number of firms with 21,000 employees (American Carpet Code N.R.A., through *Kidderminster Shuttle*, 2/9/33), though not all are manufacturers.

CHRONOLOGICAL TABLE

A—Inventions—(Taken mainly from preceding lists).

1815	Price; spirally-placed cutters acting on lower blade in shearing machine.
1832	Whytock; tapestry printing on drums with blocks.
1839	Templeton; V-fur for hard back Chenille.
1852	Collier; double shed for Brussels.
1853	Ronald; cavity-wall steam chambers.
1856	Skinner; embryo spool loom.
1857	Moxon; 3/4 wire motion.
1860	Widnell; yarn laid on metal or glass for steaming.
1863 (about)	Tapestry and velvet looms of 6/4 width in use.
1880	Skinner; more perfect spool loom.
1883	Fawcett; Childema patent.
1885 (about)	12/4 shearing machines in use.
1888	Crompton & Wyman; gripper loom, horizontal feed.
1890	Brinton & Greenwood; gripper loom, vertical feed.
1891	Youngjohn; Turkish knot loom.
1898	Tymeson; wide spool loom.
1906 (about)	Tapestry and velvet looms of 12/4 width in use.
1912	Tompkinson; knotting looms
1913	Bond Worth; carrier setting looms.
1914	Boyer } Knotting loom.
1914	Banyai }
1922	Gillette; loose knives.
1922	Grosvenor & Picking; Wilton hook loom.
1922	Dietrich; Jacquard-controlled yarn holders for fur.
1925	Frederick & Reich; horizontal knot loom.
1925	Platt; 2-needle double-insertion spool needle.
1926	Oryx; cementing coarse fibre on to backing.
1930	Morton & Oldroyd; shrogged gripper for knot loom.
1930	Platt; 3-needle single-insertion spool needle.

B—American Dates (Mohawk Mills Lecture).

1791	Spragne factory established at Philadelphia.
1810	Ingrain introduced.
1825	Jacquard inported.
1828	Sanford established.
1840	Bigelow started power ingrain looms.
1846	Tapestry and Velvet commenced at Newark N.J.
1848	Power applied to Brussels and Wilton production.
1876	Skinner invented Spool loom at Yonkers N.Y.
1878	Shuttleworths arrived at Amsterdam N.Y.
1882	McClery, Wallin and Crouse established; later amalgamated with Shuttleworths.
1909	Chenille introduced.
1916	Chenille main production started.
1920	Mohawk took in Shuttleworth.
1929	Sanford joined Bigelow Hartford and later absorbed Lowell.

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A SURVEY OF SPECIAL LOOMS OF BRITISH ORIGIN

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During recent years, many manufacturers, who previously made cotton fabrics of medium quality, have found it necessary to turn to the production of expensive cloths made with fine cotton and rayon yarns, the quality being such that no defects are permitted. Generally the weaving has been attempted on existing looms and these are not always suitable for the purpose.

As regards rayon, the yarns supplied for weaving are of excellent quality and capable of being woven without much difficulty in an ordinary loom which is kept in reasonably good condition. But faults occur in the cloth, and a high degree of skill is required from the weaver to prevent them, though such faults, which show distinctly in rayon fabrics, would not be objectionable in cotton cloths of medium quality. It has now been shown that an improvement in cloth quality can be obtained by modifying the existing loom mechanism in various ways.

This paper is an attempt to show how the standard mechanism of the loom has been modified to suit modern conditions and to describe the new types of loom which are being developed for the production of high-class fabrics. Description has been confined to two types.

Looms of Lancashire build, constructed to a very high standard of accuracy and equipped with auxiliary mechanism such as multiple box motions, improved cloth control and take-up, improved methods of shuttle picking and checking.

Looms which resemble in general appearance those used for the weaving of real silk.

When dealing with fine rayon cloths, especially those of plain weave, it has been found that the usual method of controlling the cloth when it leaves the temples has given rise to considerable creasing. Many alternative methods have been tried, such as the addition of guide rollers in contact with the taking-up roller; driving of the cloth roller by means of a slipping friction device; or inserting smoother bars of various shapes, but no method gives satisfaction with all types of cloth One system, which has been used with success, is to reverse the direction of rotation of the taking-up roller and fix a board as a guide for the cloth in its passage to the cloth roller which may be driven by a slipping friction drive or by frictional contact with the surface of the taking-up roller, as shown in Fig. 1. Taking-up motions have been modified to give accurate movement to the taking-up roller and thus ensure even spacing of the picks.

Many classes of modern rayon, or cotton and rayon union fabrics depend for their finished appearance on the insertion of two wefts of similar count and quality but twisted in opposite directions. The weft pattern consists of two picks of twist way and two picks of weft way, inserted alternately. Most loom makers will fit to an ordinary single shuttle box loom, mechanism to enable this type of cloth to be made. Such a piece of mechanism is known as a weft-mixing motion. It is operated from the bottom shaft of the loom and its use is limited to the type of cloth mentioned. When this class of box motion is used in conjunction with dobby shedding, it is easy to control the change from a spare jack and in this way any pattern which requires not more than two shuttles can be made. Even with this addition, however, the scope of such a loom is very limited. They are not popular with overlookers and cannot be compared with the usual circular or rising-and-falling box loom. It is doubtful whether the expense of converting is worth while and the present tendency appears to be to instal a good box loom of the circular or rising-and-falling type.

The usual method of driving a loom by means of fast-and-loose pulleys does not give satisfaction when weaving the finer qualities of rayon. Slow starting and stopping is responsible for bad places in the cloth and attempts have been made to improve this by fitting better brakes which stop the loom more quickly,

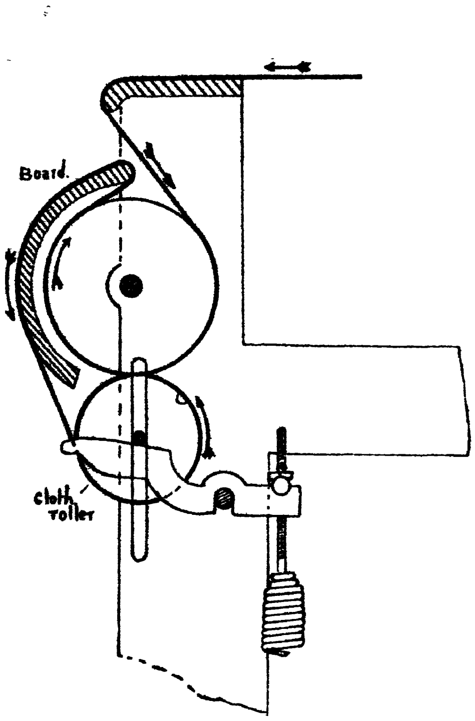

FIG. 1

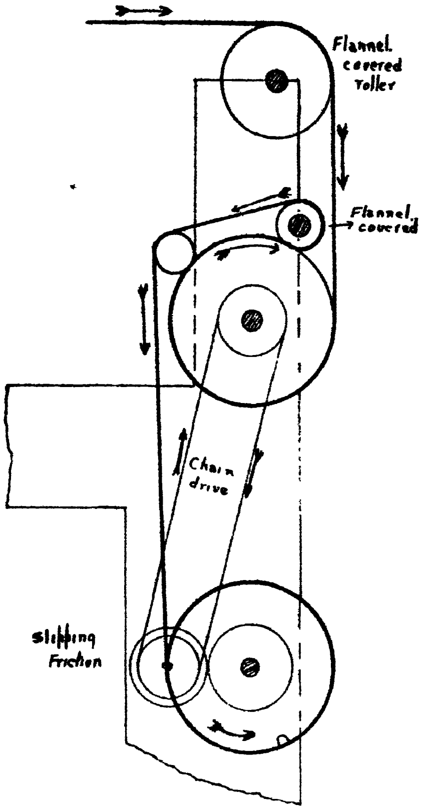

FIG. 2

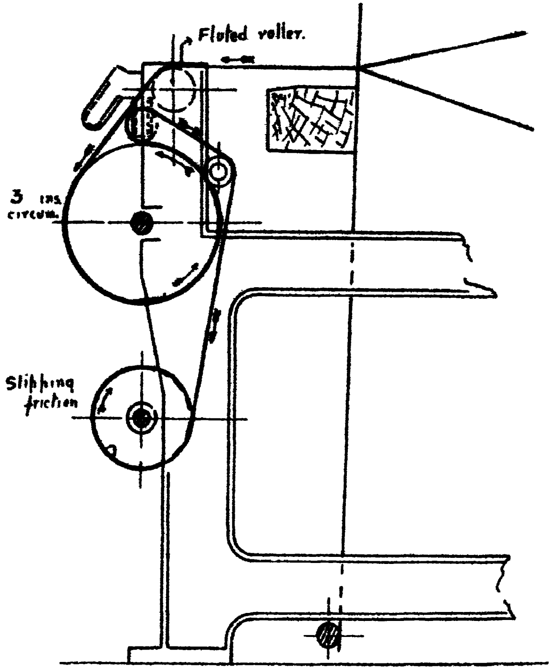

FIG. 3

and by increasing the diameter of the loom pulleys or fitting some form of friction drive to give a quick start.

In addition to the improvements mentioned it is always necessary to overhaul the loom, renew worn shafts and studs and, usually, fit a new race board. All these alterations are expensive and in parts the loom is still old and not very reliable. In many Lancashire mills the skill of the weavers and overlookers is relied upon for the production of high-class rayon fabrics on looms definitely below the required standard, even when fitted with the various modifications. It is probable that the tendency to install specially built looms for the purpose will increase, and most loom makers have designed looms with a general arrangement similar to the ordinary Lancashire loom, but with modifications to make them capable of weaving the finer cloths without the usual difficulties experienced with the old looms. Thus weavers are able to concentrate on the making of new fabrics on looms which are not entirely strange in construction.

Hattersley's Oscillating Box Loom

This loom has been designed for weaving rayon fabrics which require a weft pattern of two picks alternately from each of two shuttles. The frame is heavier than that of a similar loom of the Lancashire type, which reduces the vibration detrimental to the weaving of fine filament yarns. The two main shafts turn in bronze bushes which are carried in the loom frame and may be lifted bodily from their bearings. If desired the shafts can be fitted with roller bearings to reduce friction. The shedding motion may be either tappet or dobby. If dobby shedding is required, it is advisable, in addition, to supply a plain roller shedding motion for plain cloths as it is well known that such cloths when woven with dobby shedding cannot compare in appearance with similar cloths woven with tappets. The dobby supplied is of the inverted lever type and set at the side of the loom to prevent oil or dirt dropping on the warp or cloth, it is also easier for the overlooker to inspect the interior of the dobby. Connection between the dobby levers and heald staves is by means of leather bands which move over a series of bowls. This arrangement permits the dobby to be used on any width of loom by using a suitable length of connecting cord. A disadvantage is that the bowls are difficult to lubricate. A dobby is available which can be disconnected from the loom and reversed by hand for the purpose of finding a broken pick. This system is to be recommended as a means of preventing bad starting places which are often made by disturbing the warp tension when the loom is turned by hand to find a broken pick.

Two methods of mounting the warp beam can be used. The beam can be set to allow the yarn to pass straight into the healds, making it necessary to adjust the height of the beam according to its diameter. This is done by mounting it, along with the weighting system, on a frame which can be raised and lowered by turning a hand wheel. This method of arrangement takes up extra space behind the loom and this space is not often available in the ordinary Lancashire weaving shed. It is also doubtful if any useful purpose is served by adopting this system in preference to the older method of using a back rest in a fixed position.

The alternative method is to use a hard wooden roller mounted in ball bearings as a back rest, the position of which can be fixed permanently to suit the type of cloth being woven, irrespective of the diameter of the beam. This can be set in a convenient position under the roller, and this arrangement takes up much less space than the former.

The taking-up motion contains a single worm and worm-wheel, for which is claimed a finer adjustment of the cloth fell after a breakage of weft; no running back of the motion can take place; and no holding catch is needed. All wheels have machine-cut teeth to give more accuracy to the movement of the roller and thus to the spacing of the picks.

A difficulty often experienced when using a worm drive in the take-up, is the appearance of a slight irregularity in the cloth which occurs regularly at periods corresponding to each revolution of the worm. This is probably due to unsuitable construction of the worm drive. From actual results obtained, it would appear that not much is to be gained by the use of this type of take-up, which is obviously more expensive than an ordinary train of wheels.

A flannel-covered roller, of 3½-in. diameter, is used in place of the usual cast-iron front rest and, from this, the cloth passes on to the surface of a taking-up roller, 5-in. diameter, covered with emery or fluted rubber. Guide rollers cause the cloth to pass almost completely round the surface of the roller. The cloth roller is driven by means of a chain and slipping friction clutch to create tension in the cloth between the two rollers and further reduce any slip between the surface of the taking-up roller and the cloth, even with this arrangement it is often difficult to prevent slip when the cloth is removed from its roller, an increase in the diameter of the taking-up roller would probably give better results. The position of the cloth roller is low in the loom and this makes it difficult for the overlooker to effect any repairs under the loom without removing the roller from its bearings and this is not to be recommended on account of probable damage to the cloth. A diagram of the method of cloth control is given in Fig 2.

The loom is of the loose reed, overpick type. The slay is fitted at one side with an oscillating box of two compartments, arranged in the arc of a circle and moved backwards and forwards alternately by turning a small crank from one dead centre to the other at every revolution of the bottom shaft; thus giving a two-and-two weft pattern.

A disadvantage of this type of box, and also of the ordinary circular box with six or seven compartments, is that after a backward movement, a running shuttle has to pass over a pick of weft which extends from the selvedge to a stationary shuttle and the danger of drawing this weft into the cloth is always present, especially if the weft is of the hard twisted variety. This tendency of drawing-in may be reduced by using some form of catch thread near the selvedge, operated from the shedding motion, to lift the stationary weft over the running shuttle. A rising-and-falling box does not give the same amount of trouble in this respect.

As described, the mechanism gives only one weft pattern. It is possible where dobby shedding is used, to control the box changes from the dobby, so that any pattern with two wefts can be made, but, seeing that for all practical purposes the motion is part of an ordinary circular box, it would appear to be worth the extra expense to provide a complete circular box mechanism and have the advantage of six or seven compartments.

As with all overpick looms, the presence of a spindle over the shuttle box makes it difficult to prevent oil from finding its way from the spindle to the cloth. The underpick type appears to be finding favour in the making of expensive fabrics on account of cleanliness. Since also one of the advantages claimed for the overpick, that of high loom speed, does not enter into consideration with multiple box looms there is nothing to be gained by using the overpick in preference to the underpick. A similar loom can be obtained fitted with an underpick motion and rising-and-falling boxes.

The loom is driven by means of a friction clutch of large diameter, giving a start at full speed without any assistance from the weaver. It seems probable that many irregularities in the cloth, known as bad starting places, are caused by allowing the loom to run for several picks at a reduced speed on stopping, then starting slowly after a stop. This causes a lower rate of shed opening and, seeing that the yarn is drawn off the beam by an increasing warp tension due to shed opening, no yarn is drawn off until the first shed is made at full speed, and in this way a bad starting place is made. A good weft fork brake should be provided and fixed to the starting handle in such a way that the loom cannot be stopped without applying the brake. Such a brake can be set to stop the loom in the position required for changing shuttles or drawing in broken warp threads, and a friction clutch used for driving will enable the weaver to start the loom from the same position without assistance.

The slay is heavy and fitted with a good loose reed motion capable of weaving fairly heavy cloths and if kept in good repair will compare favourably with a fast reed loom of the same build.

Pick-at-will Drop Box Loom (Pilling)

This loom has been developed on similar lines to those of a loom for real silk to meet the demand for high-class fabrics with dobby or jacquard figuring and requiring single picks of two or more wefts. The control of the warp and cloth is similar to that of the loom previously described but for rayon warps a roller mounted in spring brackets is used as a back rest. This method of mounting corrects any variation in warp tension which may arise from the stretch of the yarn when the loom is stopped and when the taking-up motion is moved by hand.

The take-up has been modified for the purpose of weaving cloths which require variation in the counts of weft according to pattern. The speed of the taking-up roller is determined by the counts of weft inserted; the old principle of negative take-up being used. The reed is mounted in a slay cap which turns on studs, the bottom being held against the race board by a casing and springs. The reed is connected to the taking-up catch in such a way that the extra resistance to the beating up of coarse picks will press the reed back against the springs and increase the amount of movement given to the taking-up roller. The ratchet wheel is of fine pitch and acted upon by a double-pushing catch so that slight alterations in the position of the reed will have the desired effect on the amount of movement given to the roller. When weaving cloths which require the picks to be evenly spaced the taking-up motion can be used in the ordinary way.

Rising-and-falling boxes are provided at both sides of the slay and can be operated so as to insert single picks from each shuttle. When required for fabrics such as jacquard figured coutils, which are usually woven by inserting single picks from each of two shuttles alternately, two boxes are provided at each side and these are operated from the crankshaft in a similar manner to that used for ordinary weft mixing looms. If four boxes are used at each side the mechanism is such that any compartment can be brought into line with the race board when required. The boxes are controlled by the dobby or jacquard shedding; each compartment by its corresponding jack or hook in such a way that when a hook or jack is lifted the corresponding compartment is brought into line with the race board irrespective of its previous position. This system of operating shuttles boxes is becoming popular and simplifies to a large extent the arrangement of the shuttles in the various compartments. By fitting extra mechanism the compartments at each side of the slay can be controlled independently and it is possible to use seven shuttles with four boxes at each side.

The picking is of the cone underpick type. A single spindle for the picker is set in front of the box. The picking stick receives its movement from a horizontal picking shaft which is turned by a double picking tappet on the bottom shaft. Thus any advantages which the cone type of picking motion may have are retained. The method of controlling the picking according to the position of the shuttles in the boxes has been adapted from the looms used in the silk industry. The shuttle box swells at one side control the picking at the opposite side. Picking, therefore, can take place only when an empty shuttle box is in line with the race board at the opposite side. If two shuttles face each other no picking will take place. This system removes the danger of warp breakage which is present in most fast reed looms when two shuttles accidently face each other, and also makes it easier for the weaver to find the correct pattern after a breakage of weft. For the purpose of finding a broken pick, a simple movement of a hand lever will disconnect the picking box mechanism and take up while the loom is turned slowly for this purpose.

When using a loom of this type for the weaving of rayon fabrics, the choice of a shuttle is important. It is advisable to use one of the smallest dimensions allowed by the size of pirn, thereby reducing the size of shed opening required and also the distance to be moved by the boxes when changing. A shuttle which gives excellent results controls the weft yarn in such a way that it leaves the shuttle at its centre and from the inside, a groove being cut in the top to hold if clear of the boxes.

Provision is made for the weaving of plain cloth by means of a tappet and roller, the tappet supplied is adjustable as regards the size of shed made and the dwell period has been extended from the usual one-third of a pick to about two-fifths. This should be an improvement, the old-fashioned tappet with a short dwell period gave satisfactory results on high speed looms but with rayon warps of fine count and taking into account the speed at which a multiple box loom should run, an increase in the dwell period of a plain tappet will probably give better results.

Rayon and Silk Loom (W. B. White & Sons)

This loom is one of a range made by the same firm and in general build is similar to an ordinary Lancashire loom, it is fitted with the familiar cross-rod shedding motion though it can be adapted to any other kind of shedding. It has several interesting features which are worthy of a detailed description. The importance of cloth control has been recognised and the makers are able to offer alternative methods.

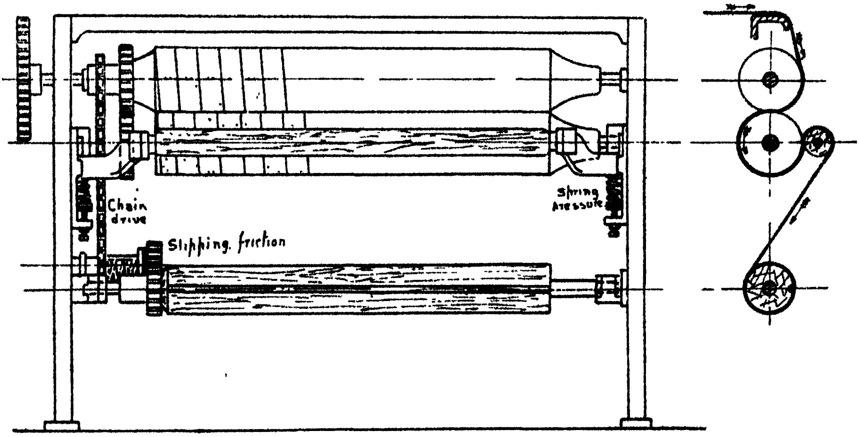

FIG. 4

A taking-up roller, 24 in. in circumference, is covered with carborundum or rubber and, to prevent slip, a metal nip roller is set in contact with the top of the take-up roller. Pressure between the surfaces is provided by springs, and this pressure can be regulated as desired. The surface of the nip roller is fluted spirally, the spiral running in opposite directions from near the centre, the object of this is to reduce the tendency of the cloth to crease as it passes on to the roller. The rollers are arranged so that the cloth passes almost completely round the surface of the roller and it should be possible to remove the cloth roller without any slip. The passage of the cloth round the rollers is shown in Fig. 3.

An alternative method is the use of two taking-up rollers which are set with their surfaces in contact (Fig. 4). The upper roller drives the lower by means of gearing and pressure between the two surfaces is provided by adjustable spiral springs which act on the bearings of the lower roller. The total roller surface covered by the cloth in its passage to the cloth roller is only slightly greater than the complete surface of one roller and seeing that both sides of the cloth are acted upon by the rough covering it seems probable that some delicate fabrics will suffer by the contact. The system in which one taking-up roller of large diameter is employed will no doubt give better results.

To prevent bad starting places being made after changing shuttles, accurate setting of the take-up is required and it is a great help to the weaver if the warp tension can remain constant during this adjustment. A pointer is geared with the ratchet wheel and set in a convenient position on a dial which has divisions corresponding to each tooth of the ratchet wheel. By turning a handle the weaver can reverse the take-up the required number of picks to bring the cloth fell into the correct position for restarting. A back roller in spring bearings will move in a direction parallel with the warp line and thus correct any reduction in warp tension which occurs due to the reversing of the take-up. This arrangement is a definite improvement on the old method of adjustment. The cloth roller is driven by means of the usual slipping friction, a method which appears to be general in this type of loom.

To further reduce the risk of bad starting places, the loom is driven with an improved type of friction clutch, giving quick starting and an efficient brake will stop the loom in one half of a pick.

The loom can be supplied with an ordinary weft-mixing motion at one side only. This is of the rising-and-falling type operated by a segment wheel which may be controlled by a pattern chain or from a dobby or jacquard machine to produce any desired pattern from two shuttles when the picks are in multiples of two. If single picks are needed, compartments are provided at both sides of the slay and in this case pick-at-will mechanism is necessary and this also can be controlled from the shedding motion. The picking motion is of the lever under-pick type, the picker sliding on a single spindle. Metal guides on the slay ensure that the correct line of movement of the picker is maintained. No spindle is used at the single box side of the slay.

The use of fine rayon and hard twisted weft makes efficient control of the shuttle necessary and the ordinary method of shuttle checking by means of a swell and check strap is not sufficiently reliable. The principle as used on some Continental looms has been adapted, this consists of two swells to control the shuttle. The inner swell is used to operate the fast reed warp protector in the usual way and the tension used on this need not be excessive. It may be regulated to suit the warp protector mechanism and its effect on the shuttle is to reduce speed as it enters the box. The actual checking is done by means of a controlled swell nearer the end of the box; the tilting of the crank arm is utilised for operating this swell, pressure being gradually applied as the shuttle enters and removed for picking so that the resistance to the movement of the picker is considerably reduced. This device gives effective checking without the use of the usual leather fittings and cleaner cloth will result. Its effect can also be felt in the smooth running of the loom.

With rising-and-falling box mechanism, some device is needed to move the picker clear of the shuttle before a change of box occurs. A connection from the stationary front rest to the box end uses the movement of the slay to stop the shuttle in the required position and afterwards move the picker clear ready for a change of boxes (Fig. 5).

A range of looms made by Messrs. Butterworth & Dickinson Ltd. is specially designed to meet most requirements for the manufacture of high-class rayon fabrics. The frames are heavy to withstand vibration and all the parts are finished to a very high standard. Being built to some extent on the lines of a silk loom, the space occupied is greater than is required for a Lancashire loom of similar capacity. If space permits, the warp beam may be mounted on a separate stand which is adjustable to suit the length of warp stretch desired, but for most purposes the loom frame may be used as a support for the beam with quite satisfactory results. The weighting system is the usual rope or chain with weighted levers. The method of controlling the cloth is similar to one already described, a taking-up roller, 30 in. in circumference, is used in conjunction with guide rollers which take the cloth almost completely round the roller. The usual slipping friction is used to coil the cloth on to its roller.

An alternative method of cloth take-up is a compensating device in which the cloth is wound direct on to the surface of the taking-up roller. A feeler on the surface controls the rate of take-up to correspond with the increasing diameter of the roller as the cloth is wound on. The mechanism is somewhat complicated but only one roller is needed and the danger of cloth slippage is entirely eliminated.

The take-up may be of the worm type with a worm of large diameter used in conjunction with machine-cut gears. Drop box mechanism is supplied either at one or both sides of the slay. The picking motion is of the side lever underpick type used with double swells for checking. The slay and shuttle boxes are constructed with such accuracy that perfect traverse of the shuttle can be relied upon, a condition that is essential for the successful weaving of fine rayon yarns. It is well known that the greatest difficulty to be overcome when dealing with looms fitted with rising-and-falling boxes is that of faulty shuttle traverse, due mainly to the lack of suitable means for accurate setting of the various shuttle compartments. This adjustment has been well provided for in the loom under consideration.

A feature worthy of mention is the provision of a device for tilting the reed during beating up. The movement of the slay is used to draw the bottom of the reed away from the cloth fell at the front centre so that beating up may take place with an inclined reed. This movement tends to correct irregularities due to weft of uneven counts. If the denier count of the weft is increased for a few picks, a corresponding increase in the resistance to beating up occurs, and then the sloping reed wires allow the cloth to slide down and thus remove to some extent the tendency to form a thick bar in the cloth. This method of beating up has also an effect on the cover produced in some classes of fabric. It cannot be said that all cloths are improved in appearance by its use but seeing that it is easy to put the mechanism out of action and use a fixed reed, it is advisable that such looms should be fitted with the device, to be used when an improvement in the cloth can be obtained.

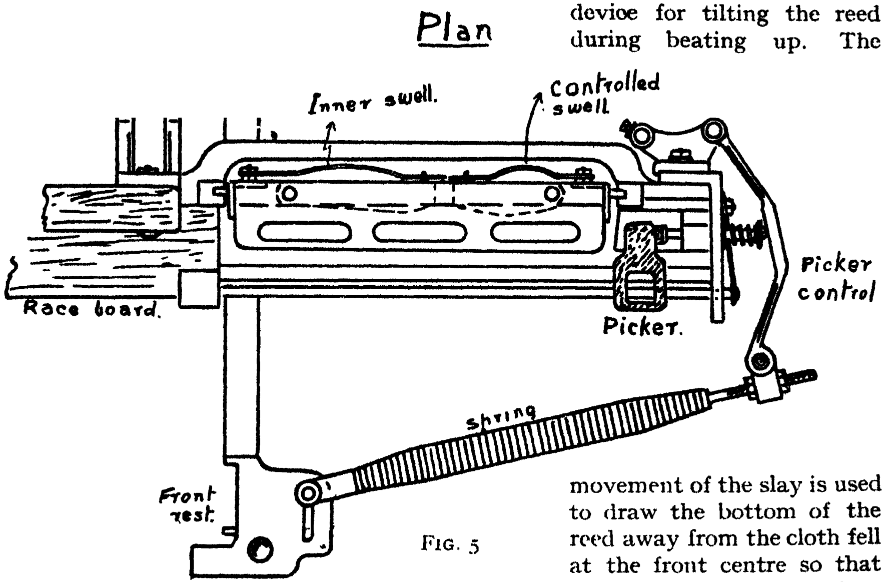

FIG. 5

The looms can be prepared for tappet, dobby, or jacquard shedding as required. A positive plain shedding motion known as a taffeta motion is recommended for some plain fabrics, this consists of a plate tappet which gives movement to wooden cones under the heald staves, each stave is connected to a different diameter of cone to give the required amount of movement according to the distance of the stave from the reed, the movement is reversed by similar cones overhead. This type of shedding does not appear to be superior to the ordinary plain roller shedding.

The looms already described are all intended for the production of similar goods, but a loom for weaving paper makers' felts of exceptionally heavy structure has mechanical details of unusual design which are well worthy of description.

Cotton Felt Loom by Messrs. Hindle, Son and Co. Ltd. Blackburn.

The loom is made in various widths, the widest up to date having a shuttle traverse of 400 inches. A loom of this width will run at 36 picks per minute. The shuttle, which is 29 inches long and will carry up to 16 oz. of weft yarn, runs over a steel shuttle race which is perfectly straight without the usual dip provided in ordinary looms.

The reed, which is exceptionally strong, is firmly fixed by its lower end in such a way that no slay cap is needed; this gives greater access of light to the cloth fell when drawing in warp threads.

The picking motion is of the lever underpick type operated from the crank shaft on the hit-and-miss principle; various points of adjustment are provided in the usual way.

In a loom of this width, eccentricity in slay movement is important and this is obtained in the usual way by means of short connecting arms. The resulting movement gives ample time for the shuttle to cross and makes it possible to use shedding tappets with between one-third and one-quarter of a pick dwell. The tappet used is of the positive plate pattern, grooves being cut into the sides of hard rolled steel plates which are carried on a shaft set at right angles to the crank shaft. This arrangement permits direct connections to be made between the ends of the treadles and the heald frames by means of a system of chains.

The take-up is positive and set to act at the beat-up, which is considered to be the correct method. The cloth is drawn forward by three heavy steel rollers and passes under the weavers' platform to be wound on to a roller behind by means of a slipping friction.

The control of the warp tension is also positive and may be adjusted from the front of the loom. The warp, as may be expected in a loom of this width, is drawn from a creel and passed between rollers which are controlled by a brake; additional drag rollers provide the necessary tension for weaving.

All these motions are on exactly the same principle as the corresponding parts in an ordinary loom, but though of exceedingly large dimensions, they are familiar and need little explanation.

The method of protecting the warp from a trapped shuttle is unusual and worthy of a more detailed description. It is well known that the fast-reed method of warp protection is mechanically unsound and has been found unsatisfactory in the loom under consideration.

The loom is belt driven by a motor on the loom top through a friction clutch which is engaged by a solenoid. There is also a control circuit with direct current of 50 volts supplied by a small D.C. generator coupled with the motor. This is used to stop the loom if a shuttle fails to arrive in the box at the correct time. When the loom is running, a powerful disc brake is held clear by means of an electro-magnet in the control circuit. A slip ring, revolving at half the speed of the crank shaft has a single gap in it which comes opposite a pair of stationary contacts during the period the shuttle is due to arrive in the box. When the shuttle arrives, the movement of the swell is used to bridge the gap in the slip ring, the control circuit is maintained and the loom continues to run. Should the shuttle fail to arrive in time, interruption of the control current takes place, powerful springs on the disc brake are released and the clutch is disengaged to stop the loom with the requisite shuttle space in the shed; this margin of safety is adjustable. When the loom is stopped in this way, the starting handle is moved to the off position to prevent the loom starting unexpectedly when the shuttle is replaced in the box. The heavy fly wheel clutch provides the energy for starting the loom from almost any position.

It is possible to use this system of warp protection is such a way that the loom stops after each pick, waits for the shuttle to arrive in the box, then starts up again automatically.

SOME WINDING INVESTIGATIONS AND DEVELOPMENTS

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(Universal Winding Co. Ltd., Manchester)

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INTRODUCTION AND SUMMARY

Certain types of defects in yarns can be removed at the winding process by suitable application of yarn clearers or slub-catchers. Some of the devices are more effective than others in removing these defects; on the other hand, owing to faulty application or design, or to wear, a slub-catcher is liable to create yarn imperfections by abrading the yarn. This action not only weakens a yarn, but scrapes off surface fibres which tend to accumulate at the slub-catcher, until they form a small bunch or button through which the yarn passes, often under increasing tension, until it breaks. Frequently a slight increase in yarn diameter, a small piece of leaf, or other impurity, will cause the end to break as it passes through such a fibre button.

Details are given of an investigation carried out in order to compare the performance of six different types of slub-catchers employed on winding machines. Records were taken of breakages during winding, and subsequently at the warping and weaving processes, and the results are analysed and discussed.

Another investigation is described, in which yarn breakages were recorded during weaving, and it is shown that if the stoppages due to fly accumulations on the yarn could be eliminated, the number of looms a weaver attends could be increased from 38 to 48. A number of suggestions are given for the prevention of these fibre accumulations.

Reference is made to a special form of lappet, which operates as a yarn cleaner and slub-catcher at the spinning frame. Better spinning has resulted from the use of this lappet, since the operatives take more care in creeling, cleaning, and piecing, knowing that carelessness increases end breakages during spinning Records are given relating to the performance of this lappet.

Close attention should be paid to the question of yarn abrasion and fly accumulation so as to reduce the tendency for fibre buttons to form.

It is urged that more investigations into the causes of end-breakages in winding, warping, and weaving should be undertaken, followed by close collaboration between the departments concerned, and particularly between the winding and spinning departments. By this means, yarn breakages could be reduced and the processes of winding, warping, and weaving carried out with greater economy.

THE REMOVAL OF YARN DEFECTS AT THE WINDING PROCESS

One of the functions of a winding machine is to remove certain imperfections from the yarns. The importance of this function is usually considered to be dependent on quality requirements; a low quality yarn may be wound with scarcely any attempt at removing defects, whilst a high quality yarn is often subjected to a very rigorous system of mechanical inspection. Actually, as will be shown, the removal of these imperfections during winding (failing their prevention at earlier processes) is of considerable importance from the economic aspect, quite apart from that of quality. The method used consists in the employment of tension and clearing devices, the latter being known as clearers or slub-catchers

The function of the tension device is to apply a controllable degree of tension to the yarn before it is finally wound into the required form, so as to remove or prevent the formation of kinks or snarls, and to build up a package of the required density. In some cases the application of tension is effective in removing weak places from a yarn, although care should be taken to see that excessive tension is not applied during winding for this purpose, as this may lead to loss in yarn elasticity which will create difficulties at subsequent processes.

The clearers or slub-catchers consist essentially of adjustable slits through which the yarn passes, the object of the slit being to prevent the passage of thick places in the yarn, such as slubs, thick piecings, undrawn roving, large knots, and tangles. They also arrest bits of leaf, seed, and other impurities, and where these are on the surface they are often removed without the yarn being broken. The slubs and other thick places, of course, result in the yarn breaking, and a knot is then tied. Whether a knot is to be preferred to a slub depends upon a number of factors, one of course being the size of the slub.

AN INVESTIGATION INTO THE PERFORMANCE OF DIFFERENT TYPES OF SLUB-CATCHERS

There are many kinds of slub-catchers used on winding machines, and the investigation to be discussed was carried out with the object of comparing the effectiveness of six different types. After the winding operation the yarns were warped on high-speed beam warpers, sized, and woven in automatic looms. A careful record was kept of yarn breakages and stoppages during winding, warping, and weaving; the cause of each stoppage or break being noted and classified. The tests were carried out at a large and progressive cotton spinning and manufacturing mill.

The yarn used was 30's carded, spun on ring frames with the Saco-Roth long draft system. For five of the tests, the winding was carried out on the Universal Winding Company's No 40 cone winding machine. On small cones, the actual average yarn speed was 769·6 yards per minute. When the cones were half-filled the average yarn speed was 776 yards, and when full the average speed was 759·6 yards per minute. These figures give an average speed throughout the winding of the cone, of 768 yards per minute, which for the purpose of calculating productive efficiencies, will be taken as representing 100%. This high speed of winding is possible owing to the absence of reciprocating mechanism in this machine; the yarn being traversed and guided by means of helical grooves in the roll on which the cone of yarn rests and by which it is driven. Abrasion between yarn and guide is also obviated in this system, since the guide is moving with the yarn at practically the same speed. The sixth test was made on the same firm's No. 60-GF machine, the average yarn speed being 507 yards per minute.

The tests were carried out on 50 spindles in the case of the No. 40 machine, and on 72 spindles in the case of the No. 60GF machine. The weight of yarn processed was approximately 2,500 lb. for each type of slub-catcher. The slub-catchers in each case were set to ·016 in. Using the formula given by Gulati and Turner,*

$$\text{Diameter of yarn (inches)} = \frac{\cdot 0748}{\sqrt{\text{count}} \times \sqrt[4]{\text{twist per inch}}}$$

the diameter of the yarn would be ·00612 in. This indicates that the slub-catcher settings were 2·6 times the yarn diameter, or ·01 in greater than the yarn diameter.

This is relatively a wide setting, because one of the objects of the investigation was to reduce the costs of manufacture, quality in this instance not being a first consideration. In short, it was desired to remove at the winding process chiefly those imperfections which would cause stoppages, and, therefore, increase production costs at subsequent stages.

Description of the Slub-catchers

The tension device, Fig. 1, was essentially the same in each case—a pair of discs mounted so as to be easily rotatable, their axes approximately vertical, the upper disc weighted according to the tension required. The yarn passes between the discs and in doing so rotates them, thus reducing friction and abrasion. The following are brief descriptions of the slub-catchers used in the tests, No 6 being the one used on the No. 60-GF machine.

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* "The Influence of Yarn Twist on the Diameters of Cotton Yarns", by A. N. Gulati and A. J. Turner, *J. Text. Inst.*, December 1930, page T561.

1—Flat blades fitted above the tension device, and at right angles to the yarn, Fig. 1.

2—"Quixset" type. Flat blade and round rod. Fitted above the tension device, Fig. 2.

3—Flat blades set obliquely to the path of the yarn. Fitted above the tension device.

4—Parallel jaws with angular grooves. Fitted above the tension device.

5—Flat blades fitted below the tension device.

6—Flat blades set level with the tension device, the yarn passing from tension to slub-catcher.

The warping speed was 400 yards per minute, from cones carried in magazine cone creels, each end being individually tensioned by revolving disc tensions similar in principle to those described. Nine beams were made in each case, with 417 ends on each beam, the length being 15,000 yards.

After slasher sizing, the yarns were woven in a set of automatic looms, 40 in. reed space. For the detection of any abnormal condition which might affect the results, observations were taken at the same time of a set of looms adjacent to those under test, and operating similar material which had gone through the normal standard preparatory processes at the mill.

Records of the Tests

The following tables are records of the six tests.

TEST A—SLUB-CATCHER NO. 1

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	196	7·1
Fibre buttons	739	27·0
Weak yarn	349	12·4
Spinners' piecings	462	16·9
Rough bobbin	8	0·3
Hard ends (undrafted roving)	89	3·2
Sloughs	267	9·8
Unknown breaks	624	22·9
	2,734	

Total bobbins run off during 52·5 hours = 12,932
Percentage of total breaks to number of bobbins run off = 21·1%
Average production per spindle = 53·9 lb.
Theoretical production at 100% on 50 spindles for 52·5 hr.—

$$\frac{768 \times 60 \times 52\cdot5 \times 50}{840 \times 30} = 4800 \text{ lb.}$$

Actual production = 2,695 lb.
Machine efficiency = 56·1%

WARPING

Beam	Cut Yarn	Weak Thread	Poor Piece-up	Wild Yarn	Bad Knot	Bad Transfer	Tangled Cone	Cone Ran Out	Fibre Button	Total Stops	Time per Beam
1	7	11	–	1	–	–	1	–	1	21	55 min.
2	3	6	–	–	–	–	–	–	–	9	50 ,,
3	1	2	–	–	–	–	–	–	1	4	50 ,,
4	–	2	–	–	–	–	–	–	2	4	45 ,,
5	1	1	–	–	–	1	–	–	3	6	45 ,,
6	1	8	–	–	–	3	–	–	4	16	65 ,,
7	3	4	–	–	–	4	–	–	9	20	70 ,,
8	2	2	–	–	–	–	–	–	1	5	45 ,,
9	–	1	–	–	–	–	–	–	–	1	

Total stops 86
Average stops per beam ... 9·5

WEAVING

Test taken on 17 looms with warps made from yarn wound on No. 40 Winder, and 11 looms with warps made from yarn wound on regular winder, for 48¾ hours. Pick indicator readings were taken daily on the 28 looms.

	17 Looms "Test A" Warps	11 Looms Reg Warps
Broken warp	586	441
Tangled warp	11	12
Slubs in warp	190	115
Beads in warp	12	12
Slack warp	4	1
Total warp stops	803 or 66·25%	581 or 65·88%
Warp stops per loom per hour	·968	1·08
Broken weft	210	149
Stopped on doff	108	63
Failed to doff	5	21
Bad bobbins	33	25
Total weft stops	356 or 29·37%	258 or 29·25%
Weft stops per loom per hour	·43	·481
Uncertain	1	1
Bang off	10	2
Loom fixer	16	26
Miscellaneous	25	11
Warp Change	1	3
Total mechanical stops	53 or 4·37%	43 or 4·87%
Mechanical stops per loom per hour	·063	·080
Total stops per loom per hour	1·46	1·64

WEAVING EFFICIENCY

	100%	Actual	Efficiency
Picks on 17 looms "Test A" warps for 48¾ hours	7,667,000	6,177,000	80·56%
Picks on 11 looms regular warps for 48¾ hours	4,961,000	3,883,000	72·27%

Picks per minute = 155

TEST B—SLUB-CATCHER No. 2

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	164	8
Fibre buttons	525	25·7.
Weak yarn	190	9·3
Spinners' piecings	455	22·3
Rough bobbin	1	·0
Undrafted roving	64	3·1
Sloughs	178	8·7
Unknown breaks	459	22·5
	2036	

Total bobbins run off during 45·5 hours = 12,603

Percentage of total breaks to number of bobbins run off = 16·15%

Average production per spindle = 51·94 lb.

Theoretical production = 4160 lb.

Actual production = 2,597 lb.

Machine efficiency = 62·43%.

WARPING

Beam	Cut Yarn	Weak Thread	Poor Piece-up	Wild Yarn	Bad Knot	Bad Transfer	Tangled Cone	Cone Ran Out	Fibre Button	Total Stops	Time per Beam
1	7	1	–	–	–	–	–	–	1	9	40 min.
2	–	2	–	–	–	–	1	–	–	3	45 ,,
3	–	1	–	–	1	–	–	–	–	2	40 ,,
4	2	4	–	–	–	1	–	–	2	9	50 ,,
*5	2	5	–	–	–	15	7	2	8	39	95 ,,
6	1	1	–	–	–	–	1	–	3	6	45 ,,
7	1	6	–	–	–	–	–	–	1	8	50 ,,
8	–	1	–	–	–	1	1	–	4	7	50 ,,
9	–	4	–	–	–	1	–	–	3	8	55 ,,

Total stops	91
Average stops per beam ...	10

WEAVING

Test taken on 16 looms with warps made from yarn wound on No. 40 winder and 12 looms with warps made from yarn wound on regular winder for 44·42 hours. Pick indicator readings were taken daily on the 28 looms.

	16 Looms "Test B" Warps	12 Looms Reg. Warps
Broken warp	318	314
Tangled warp	32	29
Slubs in warp	130	118
Loose thread	3	0
Broken heald eye	4	0
Total warp stops	487 or 58·5%	461 or 61·3%
Warp stops per loom per hour	·685	·865
Broken weft	232	202
Stopped on doff	54	41
Failed to doff	3	10
Bad bobbin	3	2
Total weft stops	292 or 35·2%	255 or 34·0%
Weft stops per loom per hour	·411	·478
Bang off	4	3
Loom fixer	17	10
Rough shuttle	11	5
Unknown	1	3
Miscellaneous	19	12
Warp change	0	2
Total mechanical stops	52 or 6·3%	35 or 4·7%
Mechanical stops per loom per hour ...	·073	·066
Total stops per loom per hour	1·17	1·41

WEAVING EFFICIENCY

	100%	Actual	Efficiency
Picks on 16 looms 44·42 hours	6,609,720	4,966,000	75·1%
,, 12 ,, 44·42 ,, ...	4,957,272	3,466,000	69·9%

Picks per minute = 155

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*The operative was changed during this test on the No. 40 machine, which accounts for the bad work in starting up the cones on this beam.

TEST C—SLUB-CATCHER No. 3

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	136	6·9
Fibre buttons	464	23·7
Weak yarn	675	34·4
Spinners' piecings	312	15·9
Rough bobbin	3	1
Undrafted roving	24	1·2
Sloughs	91	4·6
Unknown breaks	254	13·0
	1,959	

Total bobbins run off during 50·5 hours = 12,090
Percentage of total breaks to number of bobbins run off = 16·2
Average production per spindle = 50·32 lb.
Theoretical production = 4,617 lb.
Actual production = 2,541 lb.
Machine efficiency = 55·03%

WARPING

Beam	Cut Yarn	Weak Thread	Poor Piece-up	Wild Yarn	Bad Knot	Bad Transfer	Tangled Cone	Cone Ran Out	Fibre Button	Total Stops	Time per Beam
1	8	6	–	–	–	–	1	–	2	17	65 min.
2	2	1	–	–	–	1	1	–	2	7	50 ,,
3	–	2	–	1	–	1	–	–	1	4	45 ,,
4	–	2	–	–	–	–	2	–	2	6	50 ,,
5	–	–	4	–	–	–	–	–	–	4	45 ,,
6	–	6	1	–	–	10	4	–	2	23	70 ,,
7	1	4	4	–	–	3	1	–	2	15	60 ,,
8	1	7	4	–	–	–	2	–	–	14	60 ,,
9	–	1	1	–	–	–	–	–	1	3	45 ,,

Total stops 93
Average stops per beam ... 10

WEAVING

Test taken on 16 looms with warps made from yarn wound on No. 40 winder and 13 looms with warps made from yarn wound on regular winder, for 48¾ hours. Pick indicator readings were taken daily on the 29 looms.

	16 Looms "Test C" Warps	13 Looms Reg. Warps
Broken warp	674	651
Tangled warp	3	10
Slubs in warp	167	116
Beads in warp	10	48
Slack warp	4	1
Total warp stops	858 or 60·7%	826 or 72·1%
Warp stops per loom per hour	1·10	1·30
Broken weft	256	160
Stopped on doff	158	79
Failed to doff	25	5
Bad bobbin	41	36
Total weft stops	480 or 34·0%	280 or 24·5%
Weft stops per loom per hour	·615	·441
Uncertain	8	4
Bang off	18	4
Loom fixer	27	10
Miscellaneous	21	18
Warp change	1	2
Total mechanical stops	75 or 5·3%	38 or 3·4%
Mechanical stops per loom per hour ...	·096	·059
Total stops per loom per hour	1·811	1·803

WEAVING EFFICIENCY

	100%	Actual	Efficiency
Picks on 16 looms 48¾ hours, "Test C" ...	7,248,000	6,086,000	83·95%
,, 13 ,, Reg. warps for 48¾ hours	5,889,000	4,775,000	81.08%

Picks per minute = 155

TEST D—SLUB-CATCHER NO. 4

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	122	4·4
Fibre buttons	894	32·0
Weak yarn	744	26·6
Spinners' piecings	635	22·7
Rough bobbin	1	—
Undrafted roving	9	·3
Sloughs	169	6·0
Unknown break	222	7·9
	2,796	

Total bobbins run off during 47·4 hours = 12,927
Percentage of total breaks to number of bobbins run off = 21·6%
Average production per spindle = 54.67 lb
Theoretical production = 4,334 lb.
Actual production = 2,733·5 lb.
Machine efficiency = 63·07%

WARPING

Beam	Cut Yarn	Weak Thread	Slip Off Cone	Wild Yarn	Bad Knot	Poor Transfer	Tangled Cone	Fibre Button	Total Stops	Time per Beam
1	2	4	–	–	1	–	1	1	9	40 min.
2	–	2	–	–	–	–	–	–	2	35 ,,
3	–	2	1	–	–	–	1	1	5	40 ,,
4	–	3	–	–	1	–	–	–	4	40 ,,
5	–	1	2	–	–	–	1	–	4	45 ,,
6	–	4	2	–	–	4	1	–	11	55 ,,
7	2	4	1	–	1	3	2	–	13	60 ,,
8	–	–	1	–	–	–	–	–	1	40 ,,
9	–	–	1	–	1	–	–	1	3	40 ,,

Total stops 52
Average stops per beam ... 5·7

WEAVING

Test taken on 17 looms with warps made from yarn wound on No 40 winder and 11 looms with warps made from yarn wound on regular winder, for 48·75 hours. Pick indicator readings were taken daily on the 28 looms.

	17 Looms "Test D" Warps	11 Looms Reg. Warps
Broken warp	545	419
Tangled warp	28	17
Slubs in warp	199	32
Beads in warp	7	5
Slack warp	1	0
Total warp stops	780 or 55%	473 or 49%
Warp stops per loom per hour	·941	·882
Broken weft	287	225
Stopped on doff	252	194
Failed to doff	8	2
Bad bobbin	59	25
Total weft stops	606 or 42%	446 or 46%
Weft stops per loom per hour	·731	·831
Uncertain	5	3
Bang off	2	5
Loom fixer	18	12
Miscellaneous	17	19
Warp change	0	4
Total mechanical stops	42 or 3%	43 or 4%
Mechanical stops per loom per hour	·050	·080
Total stops per loom per hour	1·722	1·793

WEAVING EFFICIENCY	100%	Actual	Efficiency
Picks on 17 looms, "Test D" warps, for 48·75 hours	7,707,375	6,101,000	79·15%
,, 11 ,, reg. warps, for 48·75 hours	4,987,125	3,583,000	71·84%

Picks per minute = 155

TEST E—SLUB-CATCHER No. 5

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	133	2·8
Fibre buttons	1,547	33·0
Weak yarn	854	18·2
Spinners' piecings	821	17·5
Undrafted roving	13	·2
Sloughs	166	3·5
Unknown breaks	177	3·8
Chafed yarn	981	20·9
	4,692	

Total bobbins run off during 56·33 hours=11,815
Percentage of total breaks to munber of bobbins run off=39·7%
Average production per spindle=49·63 lb.
Theoretical production=5,150 lb.
Actual production=2,481·5 lb.
Machine efficiency=48·1%

WARPING

Beam	Cut Yarn	Weak Thread	Slip Off Cone	Wild Yarn	Bad Knot	Poor Transfer	Tangled Cone	Cone Ran Out	Fibre Button	Total Stops	Time per Beam
1	2	8	–	–	1	–	4	–	–	15	60 min.
2	2	3	–	–	1	–	–	–	1	7	50 ,,
3	2	1	2	–	–	–	1	–	–	6	50 ,,
4	–	1	1	–	–	–	1	–	–	3	45 ,,
5	–	1	3	–	–	–	1	–	–	5	45 ,,
6	7	1	2	–	–	3	2	–	1	16	60 ,,
7	3	4	2	–	–	7	1	–	–	17	65 ,,
8	2	1	1	–	1	–	–	–	–	5	45 ,,
9	–	2	1	–	–	1	1	–	1	6	50 ,,

Total stops 80
Average stops per beam ... 9

WEAVING

Test taken on 12 looms with warps made from yarn wound on No. 40 winder and 12 looms "Test X" and 6 looms "Test PP", with warps made from yarn wound on regular winder for 48¾ hours. Pick indicator readings taken daily for 39 hours. (Indicator not installed first day.)

	12 Looms "Test E"	12 Looms "Test X"	6 Looms "Test PP"
Broken warp	221	353	158
Tangled warp	3	1	1
Slubs in warp	33	58	20
Beads in warp	8	2	3
Slack warp	2	0	1
Total warp stops ...	267 or 44%	414 or 49%	183 or 48%
Warp stops per loom per hour	·4564	·70769	·6256
Broken weft	153	206	91
Stopped on doff	111	92	54
Failed to doff	21	64	17
Bad bobbin	11	14	12
Total weft stops ...	296 or 49%	376 or 44%	174 or 46%
Weft stops per loom per hour	·5059	·6427	·5948
Uncertain	2	6	6
Bang off	0	4	3
Loom fixer	18	24	5
Miscellaneous	17	17	6
Warp change	0	0	1
Total mechanical stops	37 or 7%	51 or 7%	21 or 6%
Mechanical stops per loom per hour	·0632	·08727	·0718
Total stops per loom per hour	1·0255	1·43756	1·2922

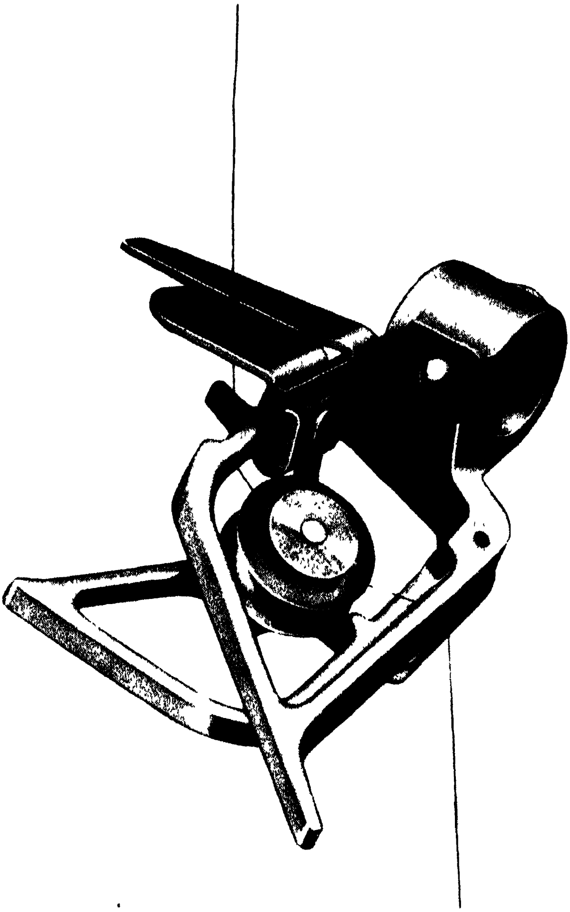


FIG. 1—General method of Tensioning the Yarn, also showing Slub-catcher No 1

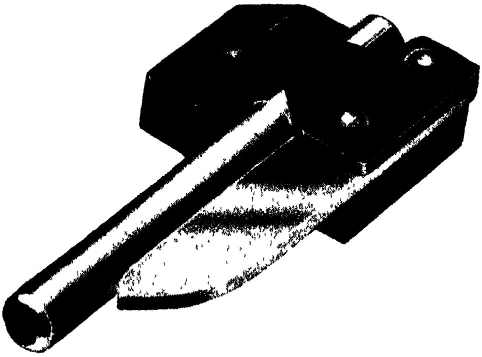
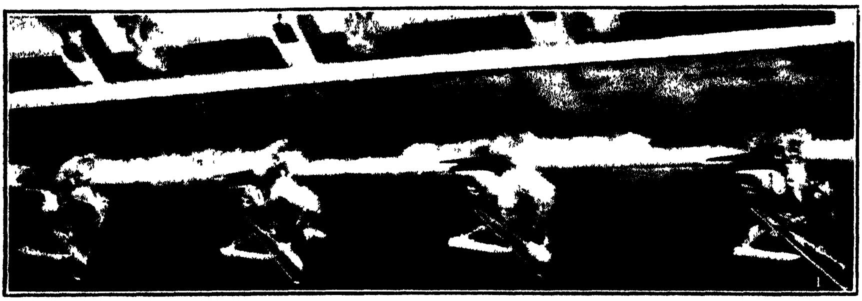
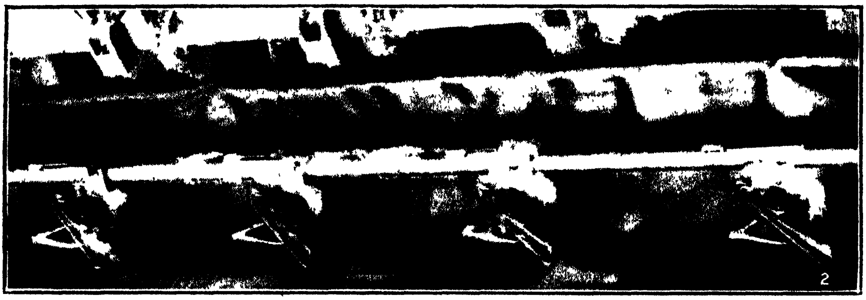


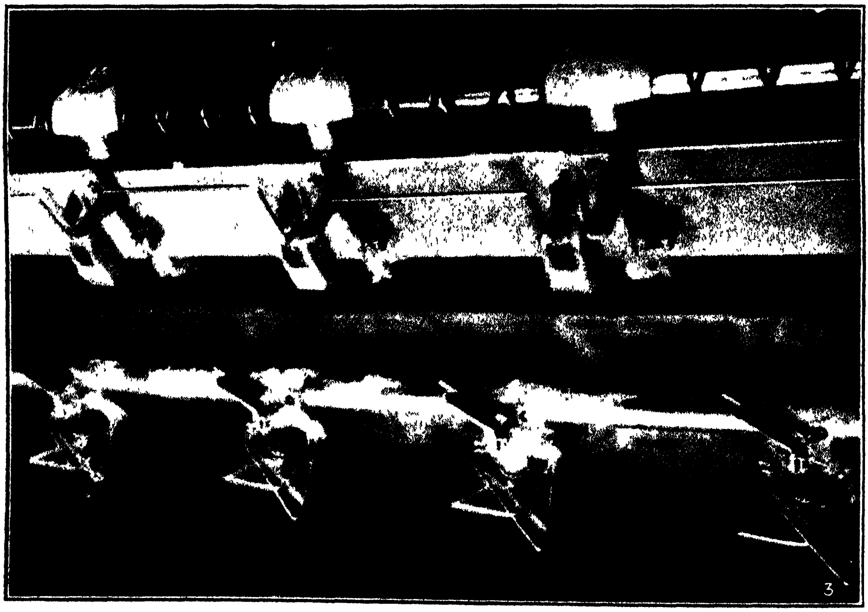
FIG. 2—"Quixset" Slub-catcher. Principle of Slub-catcher No 2



Slub-catcher No. 1

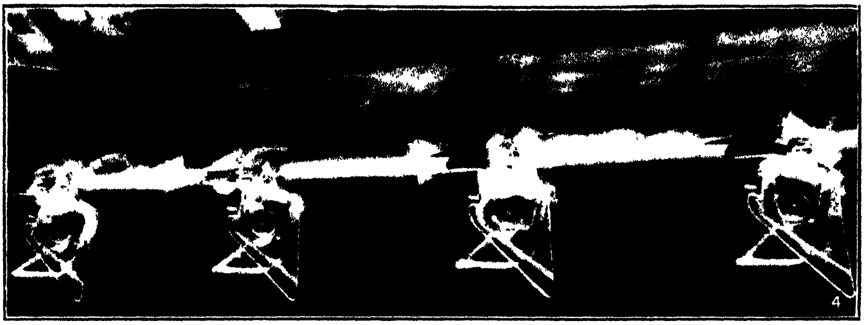


Slub-catcher No 2

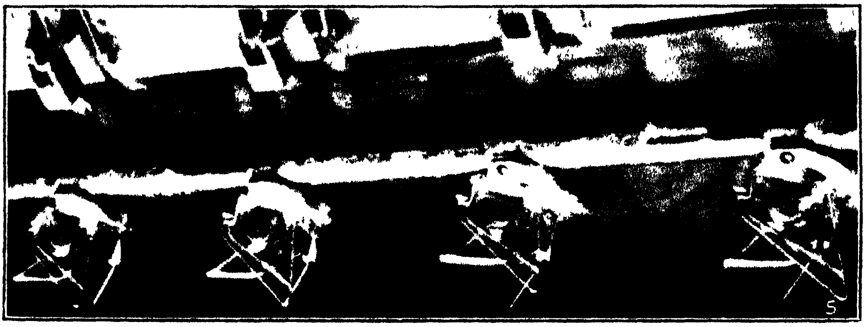


Slub-catcher No 3

FIG. 3 A—Comparisons of Fibre Accumulation



Slub-catcher No 4



Slub-catcher No 5

Fig 3 B—**Comparisions of Fibre Accumulation**

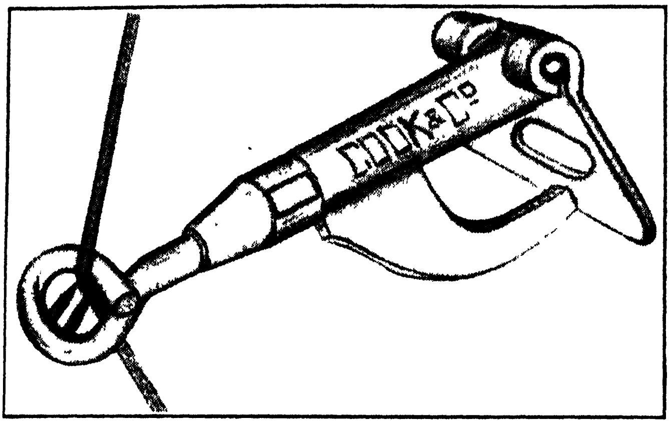


FIG 4—The "Spear" lappet, showing slub-catcher teeth.

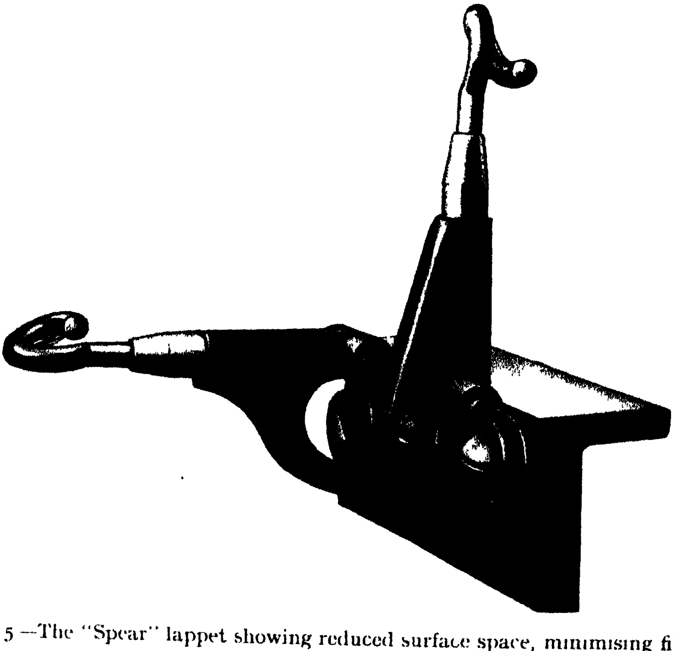


FIG 5—The "Spear" lappet showing reduced surface space, minimising fibre accumulation.

WEAVING EFFICIENCY	100%	Actual	Efficiency
Picks on 12 looms, "Test E", for 39 hours. Average speed 162 picks per minute	4,169,880	3,504,000	84·03%
Picks on 10 looms, "Test X", for 39 hours. Average speed 161 picks per minute	3,767,400	2,953,000	78·38%
Picks on 6 looms, "Test PP", for 39 hours. Average speed 161 picks per minute	2,260,440	1,755,000	77·64%

TEST F—SLUB-CATCHER NO. 6

WINDING

Cause of Break	Number of Breaks	Total Stoppages per cent.
Slubs	86	4·0
Fibre buttons	821	38·8
Weak yarn	547	25·9
Spinners' piecings	449	21·2
Undrafted roving	2	·0
Sloughs	95	4·5
Unknown breaks	114	5·4
	2,114	

Total bobbins run off during 40·83 hours = 10,117
Percentage of total breaks to number of bobbins run off = 20·8%
Average production per spindle = 30·35 lb.
Theoretical production = 3,549 lb.
Actual production = 2,185·2 lb.
Machine efficiency = 61·57%

WARPING

Beam	Cut Yarn	Weak Thread	Slip Off Cone	Wild Yarn	Bad Knot	Poor Transfer	Tangled Cone	Cone Ran Out	Fibre Button	Total Stops	Time per Beam
1	–	15	–	–	–	–	1	–	–	16	45 min.
2	–	7	–	–	–	–	1	–	–	8	50 ,,
3	–	6	–	–	–	–	–	–	–	6	35 ,,
4	–	11	–	–	–	–	1	–	–	12	40 ,,
5	–	11	–	–	–	–	–	–	–	11	50 ,,
6	–	14	–	–	–	13	–	–	–	27	60 ,,
7	–	18	–	–	1	11	1	–	–	31	65 ,,
8	–	8	–	–	–	–	–	–	–	8	40 ,,
9	–	6	–	–	–	–	–	–	–	6	40 ,,

Total stops 125
Average stops per beam ... 13·9

Weaving results are not recorded in detail in Test F, although they are summarised in a subsequent table. Test F, however, is not strictly comparable with the other results, since a much lower winding speed was employed on an entirely different type of winding machine, as well as on a different type of slub-catcher.

Summaries of the Results

The following three tables summarise the results under the separate processes.

SUMMARY OF WINDING RECORDS

The figures show the percentage of total breaks to number of bobbins run off with each of the six slub-catchers.

Slub-Catcher	Total Bobbins	Total Breaks	% of Total
No. 1	12,932	2,734	21·1
No. 2	12,603	2,036	16·1
No. 3	12,090	1,959	16·2
No. 4	12,927	2,796	21·6
No. 4	11,815	4,692	39·7
No. 6	10,117	2,114	20·8

Analysis—Per Cent. of Total Breaks

Slub-Catcher No.	1	2	3	4	5	6
Slubs	7·2	8·0	6·9	4·4	2·8	4·0
Fibre buttons ...	27·0	25·7	23·7	32·0	33·0	38·8
Weak yarn ...	12·4	9·3	34·4	26·6	18·2	25·9
Spinners' Piecings	16·9	22·3	15·9	22·7	17·5	21·2
Rough bobbin ...	0·3	—	1·0	—	0·2	—
Undrafted roving	3·2	3·1	1·2	0·3	3·5	—
Sloughs	9·8	8·7	4·6	6·0	3·5	4·5
Unknown	22·9	22·5	13·0	7·9	3·8	5·4
Chafed	—	—	—	—	20·9	—

Summary of Warping Records

Stoppage record of beams from the six slub-catchers.

Slub-Catcher	Total Stops	Average per Beam
No. 1	86	9·5
No. 2	91	10·0
No. 3	93	10·0
No. 4	52	5·7
No. 5	80	9·0
No. 6	125	13·9
	527	
Average of 54 beams		9·7

Analysis—Per Cent. of Total Stops

Slub-Catcher No.	1	2	3	4	5	Average of 5	6
Cut yarn	20·9	14·3	12·9	7·7	22·5	15·6	—
Weak thread	43·0	27·4	31·1	38·4	27·5	33·4	76·8
Slip off cone	—	—	—	15·3	15·0	6·0	—
Wild yarn	1·2	—	1·0	—	—	—	—
Bad knot	—	1·0	15·0	7·7	3·7	5·4	—
Poor transfer	9·3	19·7	15·0	13·4	13·0	14·0	19·2
Tangled cone	1·2	11·0	11·8	11·5	13·0	9·6	3·2
Cone ran out	—	2·2	—	—	3·7	1·1	—
Fibre button	24·4	24·0	12·9	5·7	3·7	14·0	—

Summary of Weaving Records

The following figures represent the comparison of warp stops from yarn wound with the six slub-catchers.

Slub-Catcher	Test Warps Per cent. Warp Stops to Total	Regular Warps Per cent. Warp Stops to Total
No. 1	66·3	65·9
No. 2	58·5	61·3
No. 3	60·7	72·1
No. 4	55·0	49·0
No. 5	44·0	48·0
No. 6	49·0	48·0

Analysis—Per Cent. of Total Warp Stops (Test Warps)

	1	2	3	4	5	6
Broken warp ...	73·0	65·4	78·5	69·9	82·7	85·2
Tangled warp ...	1·4	6·6	0·4	3·6	1·1	0·3
Slubs in warp ...	23·6	26·7	19·5	25·5	12·4	14·0
Beads in warp ...	1·5	—	1·2	0·9	3.0	0·5
Slack warp	0·5	1·3	0·4	0·1	0·8	—

Discussion of Winding Results

Taking first the summary of the winding records, it is rather remarkable that the number of stoppages due to slubs is so small—an average on all tests of only 5·55% of the total stoppages If the spinners' piecings and undrafted roving are included, however, the proportion becomes 26·85% Most stoppages are caused by fibre buttons—an average of 30% These are caused by a gradual accumulation of fibre behind the slub-catcher which ultimately causes yarn breakages, and it might be argued that in order to remove 26·85% of slubs and other thick places in the yarn, 30% additional and unnecessary breakages have resulted. The following figures have been extracted from the tables already given in order that this point may be examined more closely—

Total Breaks or Stops Per Cent.

Slub-catcher No.	1	2	3	4	5	6
Fibre buttons during winding ...	27·0	25·7	23·7	32·0	33·0	38·8
„ „ „ warping ...	24·4	24·0	12·9	5·7	3·7	—

Actual Number of Breaks or Stops Recorded

Slub-catcher No.	1	2	3	4	5	6
Fibre buttons during winding ...	739	525	464	894	1,547	821
„ „ „ warping ...	21	22	12	3	3	0

Since all the slub-catchers were set to the same gauge, it is reasonable to assume that slub-catchers No 2 and No. 3 caused least yarn abrasion. Yarn cannot be processed without subjecting it to friction by contact with tension devices, clearers, rods, guide eyes, combs, reeds, and other surfaces. Further, it usually carries a proportion of loose surface fibre (including fibre picked up during processing subsequent to spinning). Consequently fibre is certain to be removed during these processes, with the additional risk of the formation of these "buttons". The results given above, however, although they show some tendency towards reduced warp stoppages through fibre buttons, where a high proportion of breaks have occurred at the winding process from the same cause, do not indicate this as a remedy. An inspection of the photographs reproduced, Figs. 3A and 3B, which were taken after allowing fibre to accumulate for 5 hours about the first five types of slub-catchers on the winding machine, shows that No. 2 slub-catcher caused least fibre accumulation. The question of yarn contacts and abrasion is of considerable importance in the preparatory processes following spinning, and there is scope for more experimental work in this direction with a view to reducing yarn breakage.

The slough-offs indicate unsuitable build of bobbin at the ring frame for high speed winding and can usually be reduced by alteration of the ring rail traverse. Usually a slow upward and quick downward movement of the rail reduces slough-offs.

Discussion of Warping Results

The warping summary indicates a high proportion of stoppages due to weak places in the yarn—no less than 33·4% of the total, exclusive of the No. 6 slub-catcher, which shows an abnormally high percentage of stoppages from this cause. The following figures are taken from the tables.

Per Cent. of Total Breaks or Stops—Winding and Warping

Slub-catcher No.	1	2	3	4	5	6
Weak yarn during winding ...	12·0	9·3	34·4	26·6	18·2	25·9
„ „ „ warping ...	43·0	27·4	31·1	38·4	27·5	76·8

If the weak and cut yarns are grouped under one heading, the results become—

Per Cent. of Total Breaks or Stops—Winding and Warping

Slub-catcher No.	1	2	3	4	5	6
Weak yarn during winding ...	12·0	9·3	34·4	26·6	18·2	25·9
Weak and cut yarn during warping	63·9	41·7	44·0	46·1	50·0	76·8

In order to compare winding with warping, it is necessary to examine the actual number of breaks or stops rather than percentages of total. These are given below.

Actual Number of Breaks or Stops—Winding and Warping

Slub-catcher No.	1	2	3	4	5	6
Weak yarn during winding	349	190	675	744	854	547
Weak and cut yarn during warping ...	55	38	41	24	40	96

It is obvious from an examination of these figures that the problem so far as these tests are concerned is not that of taking more weak places out of the yarn during winding, but of modifying the winding conditions so as to reduce breakages at the weak places. There is a fairly close relation between the weak yarn breaks and the fibre button yarn breaks in the winding, pointing again to the question of yarn abrasion. There is one other feature worth noting, and that is that the abrasion of the yarn, which of course is influenced by the contacts the yarn makes in its passage from cop to package, had a greater effect on yarn breakage, than the actual winding speed. The winding speed on No. 6 Slub-catcher for example, where the yarn had 547 weak place breaks was 507 yards per minute, whilst thaf of the yarn going through No. 2 slub-catcher, and having 190 weak place breaks, was 768 yards per minute.

Discussion of Weaving Results

The summary of the weaving results shows that the outstanding cause of warp stops in weaving was broken warp ends, the average of the six tests being 75·8% of the total warp stops. These breaks are given in the table below, along with various classes of breaks in winding and warping.

ACTUAL BREAKS OR STOPS—WINDING, WARPING, WEAVING

Slub-catcher No.	1	2	3	4	5	6
WINDING—						
Slubs, spinner's piecings, and undrafted rovings	747	683	472	766	967	537
Fibre buttons	739	525	464	894	1,547	821
Weak yarn	349	190	675	744	854	547
Total (mean 2,089)	1,835	1,398	1,611	2,414	3,368	1,905
Efficiency % (mean 58·1) ...	56·1	62·4	55·0	63·1	48·1	61·6
WARPING—						
Fibre buttons	21	22	12	3	3	0
Weak and cut yarns	55	38	41	24	40	96
Total (mean 54)	76	60	53	27	43	96
Efficiency % (mean 74) ...	71	72	69	85	69	80
WEAVING—						
Broken warp ends—16 looms, 48¾ hours (mean 476)	551	349	674	513	295	
Slubs (mean 144)	190	130	167	199	33	
Warp stops per loom per hour ...	·968	·685	1·10	·941	·456	

In the weaving results, warp stops per loom per hour are given instead of productive efficiency, since the latter figure embraces weft and mechanical stops which are not relative to the investigation.

Consideration of the above table shows that slub-catcher No. 5 gave the lowest warp breaks in the loom with exceptionally few slubs. Warping breaks were moderate, but winding breaks were abnormally high, particularly those due to fibre buttons. Slub-catcher No. 2 gave the next lowest warp breaks in weaving and this shows a striking contrast to No 5 in having the lowest winding breaks. Although there is evidence that No. 5 slub-catcher chafed the yarn excessively the figures also show it to be an effective remover of slubs. Sizing probably has a relatively high strengthening effect on chafed yarns, and this may account for the low warp breaks in the loom. Thus slub-catcher No. 3 removed fewest slubs, had fewest fibre buttons, broke a high number of weak places in winding, and had the highest number of warp breaks in weaving. The inference is that sizing does not make slubs and thick places resistant to the chafing action of the loom to the same degree that it does chafed yarn of normal thickness. It is indeed probable that these thick places absorb or accumulate an excessive amount of size, so that they become hard and brittle, chafe excessively at the loom, and by failing to pass through the heald eyes, cause the yarn to break. This circumstance should be taken into account when the question of replacing slubs with knots at the winding frame is being considered.

A SUPPLEMENTARY TEST

Reference will now be made to an investigation carried out at another mill also dealing with the question of yarn breakages at the winding, warping, and weaving processes. In this case observations were taken on ten automatic looms over a period of ten hours. The looms were 32 in. reed, and operated at a speed of 155 picks per minute The following results were recorded.

Total warp stops	62
Total weft stops	28

Allowing for a small percentage of time lost through other causes, the corrected percentage of stops was—

Warp stops	68·52%
Weft stops	31·48%

Observations showed that an average time to repair warp breaks was 75 seconds, and for weft breaks, 38 seconds.

68·52% of 75 seconds = 51·4 seconds
31·48% of 38 „ = 12·0 „

Total 63·4 „
Breaks per loom in 10¼ hours = 9·45
9.45 × 63·4 seconds = 599 seconds
Walking time per loom 5·4 seconds (40 cycles) = 216 „
Time to repair float = 150 „
Floats per loom per 10¼ hours = 27 „

Total = 842 „
16⅔ Miscel. time = 140 „

Total time per loom = 982 „

$$\frac{3{,}600 \text{ seconds} \times 10\tfrac{1}{4} \text{ hours}}{982 \text{ seconds per loom}} = 37{\cdot}57 \text{ looms per weaver.}$$

Of the 62 warps stops, 18·3 or 25·6% were caused by fibre accumulations on the yarn, 12·9% by good knots, and 13·7% by imperfect knots.

The Effect of Eliminating Fibre Accumulations

The following calculation assumes the elimination of stoppages caused by fibre accumulations.

62 Warp stops
18·3 Stops due to fibre accumulations

43·7 = 61%
28·0 Weft stops = 39%

71·7 Total warp stops, if fibre accumulation stops eliminated.
61% of 75 seconds = 45·7 seconds
39% of 38 „ = 12·0 „

Total 57·7 „

Breaks per loom in 10¼ hours = 7·35
7·35 × 57·7 seconds = 424 seconds
Walking time per loom = 216 „
Floats per loom = 27 „

Total 667 „
16⅔ Miscel. time 111 „

Total time per loom 778 „

$$\frac{3{,}600 \text{ seconds} \times 10\tfrac{1}{4} \text{ hours}}{778 \text{ seconds}} = 47{\cdot}5 \text{ looms per weaver, if warp}$$

stoppages due to fibre accumulation were eliminated.

That is, if the winding and warping conditions could be modified in order to take out or prevent the formation of fibre accumulations, the number of looms per weaver at this mill could be increased from 38 to 48.

Suggestions for the Prevention of Fibre Accumulations

The following were some of the recommendations made as a result of the above investigation in order to reduce warp breakages at the loom through fibre accumulation.

The winding machines to be moved from the spinning room to a separate room.

Bobbin boxes to be smaller, and properly guarded in at the top

Supply spindles on winding machines to be raised and turned to project from back of supply rod This would allow more clearance between bobbins and boxes and prevent the bobbins or yarn from picking up fly on back of the bobbin boxes

All parts of the winding machine which are cut by the yarn, such as slub-catcher blades and breakage detector levers to be replaced. All such cut parts chafe the yarn and cause fibre buttons

All parts cut by the yarn on the warper or creel to be replaced or repaired, *e.g.* tensions, guides, and back combs. It was recommended that back combs should be removed to reduce the chafing of the yarn.

An extra travelling fan to be employed over the winding machines (only one employed at the time of the investigation, passing over the machines every 12 minutes). A travelling fan to be used over each warper creel.

REMOVAL OF SLUBS AT THE RING FRAME

Although the winding process is the usual place at which slubs are removed there is an alternative, namely, the spinning machine. Once the roving is drafted and is in process of being twisted it is in a condition to be cleared or slubbed, before it is actually wound on the cop or bobbin Therefore, at some point between the rollers and the spindle, a slub-catcher might be placed. An obvious position which suggests itself is the thread guide of the ring frame, and Messrs. Cook & Co., of Manchester, have recently introduced a special type of lappet, known as the "Spear" lappet, which is designed for this purpose. Two teeth or points are set inside the eye of the thread guide, as shown in the illustration, Fig. 4. During spinning the yarn is bearing against the inner face of the eye, and at the same time is rapidly traversing across this face due to the ballooning action of the yarn below the lappet. Further, the yarn is continuously rotating as it passes through the eye. The two points or spears are set in relation to each other and to the opposite side of the eye, so as to provide an effective means for removing slubs and other imperfections. The lappet is made smooth and narrow on the upper face, presenting a minimum of surface for the accumulation of fibre, and providing ample space between adjacent lappets for this fly to fall clear, Fig. 5.

It is probable that more waste would be caused by slubbing at the spinning machine, since the rollers would continue delivering the rove, and there would be a risk of this rove getting on to adjacent ends, and causing further waste. There would be more spinners' piecings, but fewer knots in the yarns. In multiple winding there would be fewer bunch knots An important result which has already shown itself in practice, is that greater care is taken by the spinning operative in making piecings, in piecing roving at the creel, in picking clearers, and in cleaning generally, since she soon realises that these attentions reduce the number of ends broken down by the lappet slub-catcher. Similarly any unusual increase in yarn defects which cause the lappets to break down more ends at the spinning machine is noticed at once, and steps are quickly taken to rectify the trouble, whether it be in the cotton itself or due to faults in the machines in the cardroom. From this point of view the lappet slub-catcher is very effective in bringing about a reduction in the number of imperfections in the yarn. Another advantage is that at the spinning machine a condition may arise at one spindle—for example, excessive fly on the clearer, or a badly covered top roller causing periodic delivery of undrafted roving—which in the ordinary course might continue producing defective yarn over a long period without detection. With the lappet slub-catcher the operative would quickly notice the frequent breakages, and take steps to remedy the trouble. It may be safely claimed for the "Spear" lappet, therefore, that its use will tend to bring about an improvement in the quality of the yarn, which in itself would reduce winding costs.

The following results were obtained in a mill investigation, using good quality yarns of low-medium and low counts.

At this mill 27% of the total stoppages at the winding frames (which in this case were multiple end machines) when not using the "Spear" lappet at the ring frame were caused by soft slubs. These soft slubs are actual thick places in the yarn, and not due to external accumulations of fly on the yarn.

When the "Spear" lappet was applied there were 9% fewer soft slubs caught in the slub-catchers at the winding frames. There were also 28% fewer spinners' piecings, 33% fewer fibre buttons, whilst the lappet took out all the faults caused by dirty fly being picked up by the yarn during spinning, due to careless cleaning etc. The fibre buttons were chiefly caused by fly and portions of drawn but untwisted rove from adjacent broken ends catching on the yarn during spinning, and subsequently being chafed into a small lump or button of fibre.

Comparative production costs showed that the extra cost of slubbing on the winding machines was 10% when there was no slubbing at the ring frame. This was reduced to 5% when the "Spear" lappet was used.

End breakages on the ring frame increased by 25% when the lappets were first applied, but these are being reduced, owing to the extra care and attention being given both by the piecer and by the management, for the reasons already given.

The economic results of slubbing at the ring frame will depend very largely on the quality of the spinning. Some mills pay extra to the spinners to take out bad ends. This extra payment could be withdrawn, and an allowance given for extra end breakage due to the use of the lappet slub-catcher. This extra allowance would be more than covered by the saving in ply-winding, and production costs would be reduced.

CONCLUSION

A general conclusion to be drawn from the investigations is that if winding, warping, and weaving costs are to be reduced, particular attention must be given to the question of preventing the formation of slubs and other thick places in the yarn, also of preventing fly or loose fibre from getting on to the surface of the yarn, and of reducing to a minimum any chafing action on the yarn. Extra attention in the spinning processes will keep down slubs and thick places, whilst systematic cleaning, with precautions against the fly being deposited on the yarn during the cleaning process, will reduce the amount of loose fibre collecting on the surface of the yarn. Careful observation will often indicate where fly is being picked up by or deposited on the yarn at various processes, and precautions can often be taken to obviate this. It might be mentioned that the use of high draft systems in spinning has resulted in more loose fibre being formed on the surface of the yarn, and this increases the amount of fly deposit at subsequent processes. Yarns spun on ring frames with separators tend to shed more fibre than those spun without separators. All parts making contact with the yarn should be smooth, and systematic inspection should be made of these parts, so that yarn-cut places can be replaced or repaired at once. There should, of course, be no unnecessary yarn contacts, and as far as possible all contact points should be so designed that the fibre removed from the yarn can fall clear, so that there is no danger of it being picked up again by the moving yarn. Given correct machine design, fans and travelling blowers are effective in preventing pockets of fibre from forming in this way. Suction cleaners are also, of course, effective, but are more costly to operate. Yarn tension devices and slub-catchers require particularly careful study and attention in order to ensure that there is no abrasion of the yarn likely to cause accumulations and fibre buttons.

In conclusion, the authors wish to stress the importance of investigations of the type given in this paper and to urge that more work of this kind should be carried out. Periodic observation and time recording tests, with classification of the yarn defects causing stoppages should be carried out and a careful analysis made of the results. Then should follow the closest possible collaboration between the various departments concerned with a view to reducing those defects which are curtailing production. Weaving stoppages, then warping stoppages, and finally winding stoppages may be traced to causes at the machine concerned, or to an earlier process, and once the cause is found, methods can usually be adopted to reduce if not entirely eliminate them. Particularly would they urge collaboration between the winding and the spinning department. Winding is a relatively costly process, therefore, although winding to-day is looked upon, and rightly, as the yarn inspection department, it should also be the *detection* department. It is not sufficient that the winding machine should prevent yarn defects going forward; this admittedly reduces subsequent warping and weaving costs, but it also increases the winding costs. The winding machine should be used in conjunction with the staff to detect and classify yarn defects. Then the causes producing these defects should be investigated by the winding and spinning departments together. In this manner, and frequently by relatively simple modifications and precautions, yarn quality can be improved, and winding as well as the subsequent processes of warping, sizing, and weaving, carried out more economically.

NEW ERA IN WOOL DRESS GOODS MANUFACTURE
MODERN CLOTH DESIGNING

By Eber Midgley, F.T.I.
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The textile industry of Yorkshire has witnessed numerous departures from ideas and methods which were common up to a few years ago, when it was the rule for spinners and manufacturers to run year-after-year on a comparatively few types of yarns and fabrics, employing one particular type of material. To-day woollens, worsteds, cottons, silks and the various types of rayons, once separate and distinct, have encroached on one another and are now found in combination in adjacent looms in a weaving shed.

Traditional Methods Violated

The dictates of fashion together with the present-day new conditions have compelled dress goods manufacturers to produce cloths which violate the traditional systems of cloth construction.

Prior to 1928 most dress fabrics possessed a smooth and level surface and were composed of warp and weft threads, closely "sett" in the loom. Such setting allowed only slight variation—about 9%—from grey to finished cloth, hence might be described as "made in the loom". They relied on their saleability, to weave variation, durability, colour and finish.

To-day the demand of the garment designers is for cloths possessing new and novel characteristics. Every new style of fabric which has been started during the last four or five years has been due to one or more of the following factors—

(*a*) Combination of two or more types of material.
(*b*) Unusual structure of yarn.
(*c*) Suitable treatment during dyeing and finishing, according to the constituents of the fabric and appearance required.

The utilisation of these factors provide unlimited opportunity for the production of new effects. An outstanding feature in the construction of most of the new fabrics is that the traditional rule of "setting cloths according to diameter of yarn" is completely ignored. Many of these cloths are "sett" in the loom approximately 40% below the actual diameter of the yarns employed. During cloth finishing a shrinkage of about 20% takes place from grey to finished cloth during which the desired character of fabric is produced. By modifying the processes or degree of treatment during cloth finishing, varied effects are obtained. Whereas previously dress cloths were "made in the loom" present day fabrics are "made during finishing".

Light-weight Fabrics: Use of Rayon

The marked development in the manufacture of fine rayon yarns has made it possible to produce new types of fabrics, extremely light in weight, which also meet the demand for fine fabrics. To illustrate the possibilities in this direction it might be mentioned that a 2/60's botany warp yarn—the basis of the lightweight worsted cloths—is twice the diameter of a 75 denier rayon yarn, which is extensively produced to-day.

The increased production of rayon in the United Kingdom from 25 million lb. as in 1926 to 84 million lb. as in 1933—although also used for other purposes—indicates to some extent the increased large volume of trade in dress goods, partly or wholly, of this material. Extremely lightweight fabrics fine in texture are extensively produced with 100% rayon and also with rayon warp and fine botany worsted or cotton in the weft.

Crêpe Cloths

The employment of hard-twisted yarns, provided opportunities for producing new styles in fabrics. In the first instance the cloth known as "georgette" was composed of warp and weft threads arrranged alternately in opposite directions of twist, and when leaving the loom, it resembles an ordinary and somewhat coarse plain woven fabric. During the subsequent wet finishing processes by natural or by chemical treatment, both the warp and weft threads change from a straight to a wavy formation, giving the cloth a crêpe appearance together with being semi-transparent and light in weight.

Cloths made from a combination of these two yarns in different order for both warp and weft provide strikingly different types of crêpe effect. At the present time there are going into consumption at least a dozen different crêpe cloths, each being distinctive and individual, known by such terms as crêpe-de-chine, sand crêpe, crakle crêpe, crêpon, elephant skin, etc. Weave variation in these structures is practically non-existent, plain weave, hopsack, a few simple twills and diagonals being the most useful.

Spinners' Cloths

The combination of different materials in yarns and the employment of unusual structures in them, also provided opportunities for producing new and novel styles in fabrics. The introduction of such yarns marked the era of designing cloths which relied on their saleability and novel appearance upon yarns designed for a specific purpose.

In wool fabrics, which are usually piece-dyed, two or more materials possessing different chemical properties are combined. Rayon (acetate and viscose) and cotton, both white and coloured (fast to wool dyeing) are employed in large quantities for two or more colours for spotting, checking, or twist effect.

The production of these yarns calls for knowledge and experience in selecting suitable materials. It is of vital importance to obtain the correct colour combination and handle in the resultant dyed and finished fabric. The correct proportion of each different material is essential, as an insufficient or excess amount of one component seriously detracts from the appearance of the finished cloth. To attempt to enumerate the structure of the many types of yarn which are being extensively produced is beyond the scope of this paper. Two examples are chosen and are as follows.

(*a*) *Ondé Yarns*—Yarns of this type present an obstacle which a designer has to overcome on account of the comparatively coarse count (1/14's worsted count being the limit); they are produced to provide a definite ondé or ripple appearance. The components of a simple ondé yarn are a good quality woollen yarn twisted with a crêpe-twist single botany thread. Many variations have been made, such as blending rayon (viscose) with the woollen prior to twisting with the crêpe worsted; crêpe woollen and crêpe worsted have been combined; the scribbling of a percentage of fast-dyed black wool into the white woollen; and also right and left twist ondé yarns. Any one of these variations adds some new features to a fabric where such yarns are components. Varying warping and wefting orders along with ordinary twist yarns provide great opportunity for the production of a variety of effects.

Another important economic factor connected with processing is that they can be produced on an ordinary twisting machine.

The construction of such a yarn is—Base thread, 1/32's botany crêpe (ungassed), 25 turns per inch. The other component being a 22 skeins woollen, 8–9 turns weft twist, opposite direction of the worsted. When folding the yarns together 8 turns per inch are used; resulting in the crêpe yarn contracting slightly when tension is released, imparting the ripple on the ondé effect.

(*b*) *Bouclé Yarns*—This is a type of yarn which lends itself to designing dress cloths and although the range of counts cannot be termed large, it is counterbalanced by the combination of different materials. The posibilities in this direction are exceptionally great, for the yarn can be made from all worsted, woollen, cotton, and rayon, or botany and viscose, cotton and acetate rayon, woollen viscose and worsted, cotton and woollen with 25% viscose rayon, scribbled in the woollen.

The yarn is definitely a fancy yarn and requires a fancy twisting frame for its production, as will be gathered from the following particulars.

Base thread, 1/52's cotton, printed fast to cross dyeing colours. This is twisted with a 1/52's white cotton, 4–5 turns per inch. The next operation is to fold the above yarn with 100 denier rayon thread, the excess delivery of yarn being 31 in. in every yard of twist. In the final operation, the bouclé effect is bound securely with 1/40's white botany 7 turns per inch. The finished yarn has a resultant count equal to 13½'s worsted, and contains 35% botany, 32% rayon, and 33% cotton.

Unusual Combination of Materials

An outstanding feature is the large quantities of yarn spun on the woollen principle, in the production of present-day wool dress fabrics. This is due to the demand for cloths which are not only full and soft in handle, but which have a definite amount of one or more materials blended together and all components indicating their presence. Attempts to produce this character of yarn on the worsted principle has indicated that the combing, gilling, and drawing operations parallelise the fibres to such an extent that the desired effect is greatly obscured.

This type of yarn has been exploited to a great extent by blending wool with one or other of the following materials—camel hair, alpaca, rabbit hair, ramie, rayon kemps, and natural kemps.

In every instance, a definite amount of each material is blended which enables different degrees of contrast in the resultant fabric, and which may within limits be varied. Where wool and hair are combined, it necessitates much care due to the difficulty in controlling both fibres.

The most recent efforts have been directed towards the production of kempy effects and these in the initial stages were produced from kempy wool. Such wools have been marketed at a low price but with a change in fashion they are in greater demand. The effect is produced in piece dyeing, the wool being a deeper shade than the kemp, hence the speckled appearance. To obtain more pronounced kempy effects, mohair, jute, and rayon were used advantageously.

The mohair, and also immunised wool kemps, resisted the wool dye much better than the ordinary wool kemps, while the jute and rayon (bast and synthetic fibres) were not affected by the wool dye. Coloured rayon is being used in these yarns, thus increasing the range of yarns and variety of cloths.

When first introduced the yarns were used solid in weft and occasionally in warp, but, in the new season's fabrics, have found application as striping and checking threads and picks.

Flax is a fibre that manufacturers have used with advantage in obtaining new character of dress fabrics. It is essentially the fibre for summer cloths, and will be employed in many garments designed for comfort where high temperatures can be relied on for long periods. Both natural and bleached linen are employed occasionally on the same yarn, mixture effects, knops, and crêpe and bouclé effects being possible.

Tinsel yarns are being more extensively employed than previously. Their application is definitely for effect purposes, but where used demand skill in warping, weaving, and finishing As a substitute rayon yarn metallic in appearance is employed, which offers better facilities for processing than tinsel.

Training of Designers

In modern dress fabrics, beauty of design and texture is obtained by the combination of suitable raw materials by the clever manipulation of fibres into yarn, and by suitable cloth finishing, and not by laborious treatment at the loom. The whole trend in design seems to be towards the unorthodox and even the grotesque, so far as cloth construction is concerned.

It cannot be too frequently stressed that the present-day designing of dress goods is a scientific manipulation of all types of conditions of fibres and yarn rather than an art. The cloth designer, to meet present-day conditions, requires a much more extensive training than hitherto. Not only must he possess a highly specialised knowledge of cloth construction, weaving mechanisms, etc. but also a fundamental knowledge of the chemical and physical properties of all the various types of textile fibres, together with the possibilities of the various methods of yarn manufacture and also the influence of cloth finishing processes on all types of yarn and cloth structures.

The necessity of such a training is indicated in advertisements which have recently appeared for "Dress Goods Designers" where, in addition to ordinary qualifications, candidates are required to have a knowledge of various types of rayon; cotton and wool yarns; all types of crêpe yarns; and of dyestuffs and colouring matters.

The creation of demand for new styles of cloth is the responsibility of the cloth designer and it is the demand which ultimately creates the supply.

Production was never on a higher plane in the textile industry than it is to-day. The eagerness shown by foreign manufacturers to copy British cloths in cheaper imitations as soon as they appear is a tribute to the originality and ability of Yorkshire designers. It is on account of this piracy that many manufacturers are so reluctant to display their productions at the British Industries Fair.

MODERN FABRIC STRUCTURES IN THE SCOTTISH WOOLLEN TRADE

By D. R Christie, A.T.I.
(Peter Anderson Ltd., Galashiels)

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However far we may investigate modern structures in Textile fabrics, we shall no doubt find that, while certain structures are claimed to be new, they are really only a new application of some little known structure; or in other cases, a structure well known to one section of the industry has been modified and applied in a novel form to another section of the industry. From time to time we find a particular form of fabric structure exploited in one or more branches of the industry. The success of such a structure will depend largely upon the skill of the designer and the utility of the fabric from the users' standpoint, i.e. its novelty in appearance; suitability for making-up; and, to some extent, its wearing properties.

Scotch Tweeds have always been famed for their excellent wearing properties, and their beautiful colourings. Very little depended upon novel weave structures, except that the weaves used should be of firm build. Thus the common twill or "tweel" became the basis of the majority of Scotch Tweeds. Only the simpler weave elements were included, and the attractiveness of the fabric had to depend upon combination of colours. In this respect, the colourings associated with Scotch Tweeds are admitted to be the most beautiful that can be obtained in woollen cloth. The Scottish Clan Tartans provide an excellent illustration of the colour taste that has been inherent in the Scottish race for centuries. During recent seasons we have seen, in modern woollen scarves, the designers' skill in combining colours. While boldness of style is the feature of most of these patterns, yet the combination of colours has a most pleasing effect.

NEW STRUCTURES FOR MEN'S WEAR

Suitings

In the men's wear section of the industry, we find that the majority of fabrics are still confined to the simplest of weave structures, and when special weaves are introduced they are used primarily for decorative purposes. In the suiting section the simple twill ground has been enhanced by the introduction of striping elements comprising different weave structures. Crammed line stripes have been an outstanding feature in Scotch Tweed suitings for many seasons, and in addition to drafted stripes on the twill basis, other weave interlacings have been skilfully introduced for this purpose though still retaining the essential properties of the ground texture. It will be evident to those principally concerned with the suiting section that there are many restrictions imposed upon the designer. But these same restrictions have led the designer to exploit to the full the few elements at his disposal, resulting in an enormous range of novel styles. The 3–2–1–2 interlacing is extremely useful as a striping element in fancy suitings, and the variations of this element in conjunction with the common twill opened up a wide field for decorative stripes. The cramming of silk, and silk and worsted marls, into these cloths is often very extensive, and frequently involves as many striping threads as there are ground threads.

In the designing of suitings for sports wear, greater use has been made of fancy weaves. These weave effects, however, are mainly the result of combining four shaft weave elements which include common twill, crow twills, 3–2–1–2 step 2, celtic, and cords, also variations of these. Two or more of these elements are combined on various schemes, but generally upon bases which admit of drafting on groups of 4 shafts. Designs of the "gamefeather" type are produced by these simple weave combinations, and in conjunction with marl yarns yield very attractive effects. Fig. 1 is a typical example of schemes used in designing these figured styles.

Fig. 1

A	C	B	D	D	B	C	A
D	B	B	D	A	C	C	A
D	D	B	B	C	C	A	A
B	D	D	B	C	A	A	C
C	A	D	B	B	D	A	C
C	A	A	C	B	D	D	B
A	A	C	C	B	B	D	D
A	C	C	A	D	B	B	D

A = 2-2 twill Right
B = 2-2 twill Left
C = 3-2-1-2 step 2 Right
D = 3-2-1-2 step 2 Left

Overcoatings

The overcoating section admits of greater scope for the introduction of novel weave structures, as compound fabrics are more in evidence. The checked-back overcoating with its extra warp stitching thread must have given its inventor the thrill of placing a new fabric on the market. I understand that in experimenting with this new method of stitching in double cloths that the test was to see how firmly the cloths could be bound together. In the first trials the cloths were so easily pulled apart that it seemed to be an unsatisfactory method of stitching, but the fault was soon overcome, and now we have a method of stitching which is extensively used in double cloths. It may be that this method of stitching resulted from the examination of extra warp or weft fabrics in which extra stitching threads were used for tying the loose back floats to the ground. In any event, its introduction has made it possible to weave fancy rugs and overcoatings in which bright coloured check styles or tartans can be combined with plain cloths without the colours showing through at the stitching points. Another advantage from its use is that it produces a fuller handling cloth than that obtained by ordinary stitching.

As an illustration of transference of a scheme of design from one type of fabric to another in quite a different category, we have the spot vesting designs generally developed in neat spot and figured effects utilised in the decoration of fancy overcoatings, and generally described as "spot-backs". In these, use is made of the treble cloth structure in which the lining and centre cloths are interchanged for figuring on the lining side of the cloth. In other structures, for example, a double cloth in which one or two extra wefts are used for more elaborate effects, weaving is done on a comparatively small number of shafts. This latter feature is constantly recurring in the development of the more elaborately designed fabrics since the majority of looms in the Scotch Tweed trade have a maximum capacity of only 24 shafts. Thus certain modifications in structure of compound fabrics have to be made to admit of the production of the more elaborate effects. If one extra weft is employed in double cloth, a very effective imitation of the treble cloth spot back is obtained on 12 shafts. The extra weft is laid as wadding in the ground section and interlaces 1-3 twill with the lining warp in the spot section as illustrated in Fig. 2. When two extra wefts are used, more novel spot patterns are obtained on a minimum of 16 shafts. Whichever method of figuring is used, the face cloth must not show any trace of the figured patterns on the lining.

Another interesting structure in the overcoating group is the imitation pile or "tufted" fabric, in which the finishing processes play an important part.

The foundation fabric is usually a double cloth with two extra wefts arranged to show weft cord stripe, corkscrew twill, herringbone, and diamond effects on the face of the cloth. The subsequent finishing operations employed break up the weft floats, leaving the extra wefts as tufts on the face of the fabric. These are well secured to the foundation fabric, and the cloth is remarkable for lasting wear. Fig. 3 illustrates the construction. This principle is also applied to ladies' coatings in single cloth, with floating weft and plain alternatively, but the fabrics are not so durable as those with a double cloth foundation.

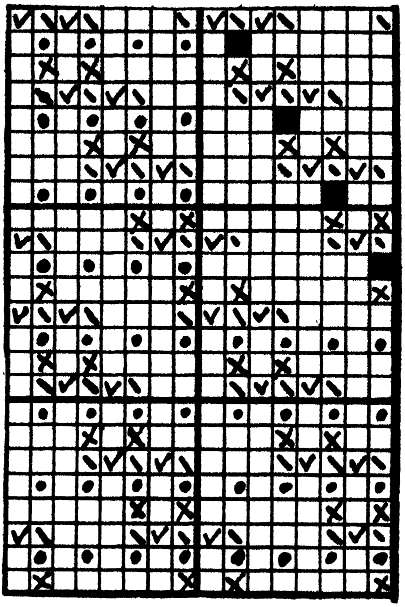

FIG. 2

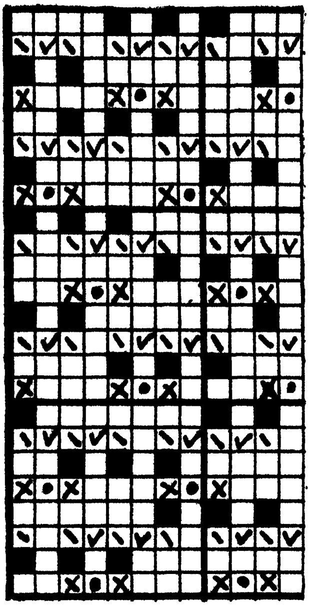

FIG. 3

NOVELTY TWEEDS FOR WOMEN'S WEAR

The greatly increased demand for novelty of effect in women's wear fabrics during recent years has led to the introduction of special fabric structures to one or more groups of fabrics associated with this section of the trade.

Gauze

The demand for woollen dress goods of exceptionally light weights was largely responsible for the introduction of gauze weaving into the women's wear section of the industry. In ordinary weaves, the setting required to give the desired weights was much too open to admit of obtaining a sufficiently firm structure for tailoring or wearing purposes. In gauze weaving, an interlocking type of structure is formed which prevents warp and weft slipping and yields a fabric which though open is comparatively firm. Although difficulties were at first experienced in weaving gauze on the open-shed dobby looms used throughout the trade, these were quickly overcome. Certain additional attachments are necessary, but being simple in construction they can be made and fitted by the mill engineer or loom tuner. Only the simpler structures of gauze have been used and mostly confined to one-doup effects. This weave structure has been applied to a wide range of fabrics from light weight dress goods to novelty coating tweeds, and designers were quick to realise its possibilities in colour arrangements. The combining of yarns of different counts and the grouping and spacing of threads in the reed splits in various orders, in conjunction with blank picking, have resulted in considerable variation in effect with a few simple weaving plans Both single-beam and double-beam arrangements are used, and in working the two-beam arrangement, it is important that the tension of the two warps is kept in the same relationship during weaving, as any uneveness in tension causes strong barriness weft-way; especially if the two warps are of contrasting colours Special fabrics such as the cellular blanket have resulted from the use of this structure.

It is interesting to read in Ashenhurst's "Design in Textile Fabrics" dealing with materials suitable for gauze that "woollen yarns are quite unsuited for making gauze cloths . . . though if well twisted they may be employed in making the heavier goods when gauze is combined with twill or other forms of pattern and where clearly defined patterns are not needed".

Imitation gauze and leno weaves have been successfully applied in securing novelty of effect in women's wear fabrics. The simple imitation gauze on 6 × 6 (Fig. 4) has been extremely useful in this direction. It gives a light weight open texture of comparative firmness, and its peculiar combination of tight and loose interlaced threads and picks, yields many novel effects from simple colour patterns which appear quite ordinary in plain or twill fabrics. It is combined with plain weave for figured effects in which its open texture is in striking contrast to the plain cloth. These figured designs can be arranged to weave on comparatively few shafts as two-thirds of the threads are weavable on two shafts.

Imitation leno weaves have also been freely used in fancy dress and coating tweeds, and from these considerable variety of effect is obtained by the distortion of certain threads and picks which lie for the most part on the face of the fabric. These weaves are also combined with plain or twill weaves for more elaborate patterns.

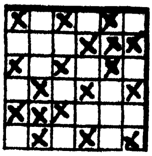

FIG. 4

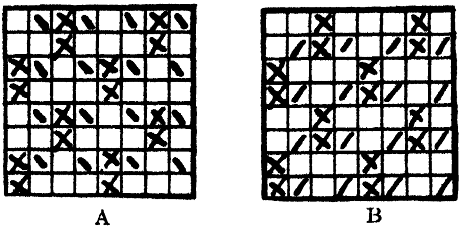

FIG. 5

Woven Tucks

The woven tuck or pleated fabric is another interesting type of structure which has been fairly successful, although effects are more limited in this make of fabric. Two warps are required for the simplest form, the warp forming the tuck is given a greater delivery than the ground warp. It is also necessary to have a cramming motion attached to the loom, and brought into operation when the picks forming the tuck are being inserted. The tuck can be arranged to extend from selvedge to selvedge without interruption, or may be arranged with sections of plain ground alternately or in other formations. By using two or more counts of yarn for the "tucking" warp, arranged in different styles, variation can be given to the simplest weave form. If two extra beams are used, the tucks can be arranged in alternate order with the ground both lengthways and width ways. The introduction of a fourth beam would admit of a twill formation being produced. The spacing of the tucks can be varied at will, but when close spacing is practised considerable weight is added to the fabric, and the extra picking greatly increases the cost of weaving The ground cloth between the tucks is woven as simple twill or celtic, but in the tuck, the warps are separated: one warp interlacing the weft, the other floating on the back.

THE USE OF LASTEX

This thread has a rubber core covered with cotton, wool, linen or silk The main principle underlying the use of these yarns in woollen cloths is to increase their elasticity. Secondly, they are used for effect, and crêpon and crinkled effects are easily obtainable by the introduction of a single pick of Lastex yarn every ¼ inch or so. With special weave arrangements, it is possible to obtain a wide range of undulating effects including cord stripes, diagonals, waves, diamonds, etc. The yarn may be used as supplied by the makers, and is obtainable with different degrees of elasticity, or it may be twisted with a woollen yarn. The latter type has been used in the production of flat cloths which look like ordinary tweeds, but which have a greater degree of stretch than the same tweeds made without Lastex yarn. Both types of cloth have been taken up by garment makers, and much will depend on the success of their efforts as to the new cloth becoming a staple fabric.

In weaving, the Lastex as supplied by the makers (mostly used in weft) the problem of drag had to be overcome, and this varied in the different types of Lastex yarns. Generally, however, a full drag is applied, and by using half-pirns a uniform fabric is obtained. When finishing one pirn and starting another, care has to be taken to see that the Lastex is not allowed to run slack, and the pirn should not be allowed to run quite empty. When the Lastex is twisted with woollen ordinary drag is sufficient and little difficulty is experienced in the weaving of these either in warp or weft.

FIGURE DESIGNING ON DOBBY LOOMS

As there are few jacquard looms available in the Scotch Tweed trade, and the majority of looms have a capacity of only 16–24 shafts, various schemes have been adopted in drafting arrangements and pegging to secure large figure designs in woollen tweeds which will come within the range of shafts available. The following design elements, Fig. 5 A and B, illustrate how a wide variety of figure designs can be arranged to weave on a comparatively small number of shafts.

It will be observed that the 2–2 interlacing is common to both A and B, and that plain and reverse plain threads complete the designs. By changing from plain to reverse plain, the wefts are interchanged from face to back and vice versa. Thus by using the one-and-one colour arrangement in weft the design effect is clearly developed. The pattern illustrated in Fig. 6 is weavable on 12 shafts by combining A and B.

BORDERED STYLES

The popularity of fancy bordered styles in ladies' coating tweeds a few years ago resulted in the introduction of many ingenious methods for weaving plain ground in one section of the width and fancy border in another section. The border styles varied from a few inches to half width. The double plain weave was used fairly extensively, and its principal feature for this style of pattern is that the design effect can be developed in one section of the warp, and obliterated in another section, by reversing the simple one-and-one colour pattern usually associated with double plain designing. Extra warp designs are also very suitable for these styles, and, by arranging 4 ground 1 figuring, it was possible to secure many fancy effects on very few shafts. Elaborate drafting arrangements are usually required for the border styles, and peg plans would be arranged to give designs ranging from about 6 inches to 12 inches long. These effects, however, illustrate very clearly the great adaptability of the bobby loom for style requirements. Some very ingenious loom mountings have been used in single cloths made with fancy borders. The principle underlying these was to have a pick of one colour interlacing with one section of the warp, while another colour of weft was woven into the remainder of the warp. This was done without showing any objectionable floats in the cloth, the two colours of weft being looped together at the change. By various arrangements of drafting and pegging it is possible to weave a single cloth with one-half to two-thirds of the width solid colour and the remaining section formed by pinnacle or "sky-scraper" designs in one or more colours and ground.

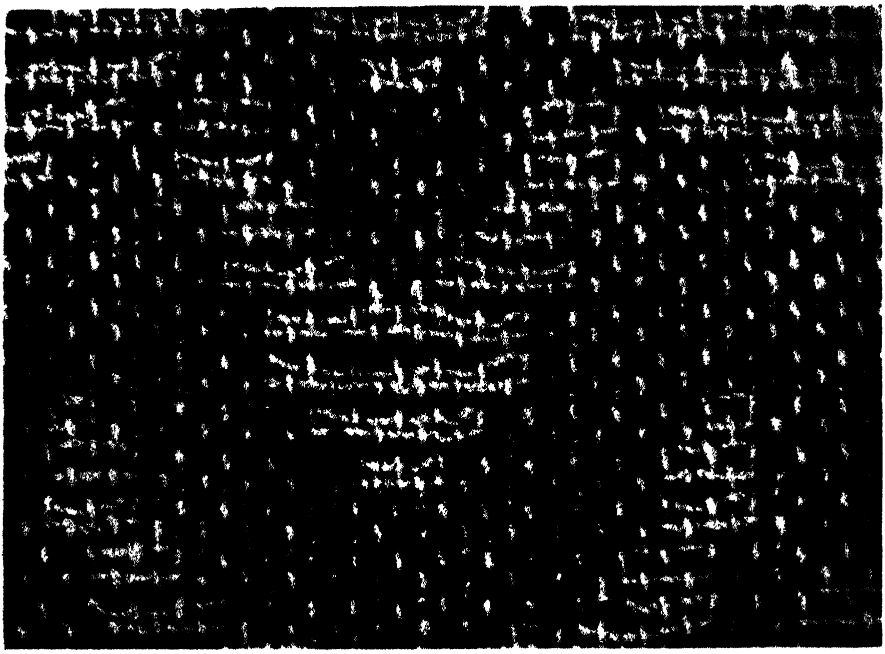

FIG. 6 (×2)

Novelty effects due to the introduction of fancy yarns are numerous, and while the majority of these yarns do not require any special weave structure to bring out their outstanding feature in the woven fabric, some consideration has to be given to the setting and spacing at the loom. Yarns dyed so that one-half of the hank is one colour and the other half another colour require special attention as the width of the warp has to be adjusted to suit the length of hank, if the symmetry of the effect is to be maintained. These yarns when woven into cloth yield most striking effects. They are used for all-over patterns and combined with plain yarns for bordered styles, e.g. one-half yard woven with fancy yarn and two-and-a-half yards plain.

Tweed furnishing fabrics illustrate an attempt by some firms to enter into a new section of the industry, although we have seen in recent times the application of tweed colourings to cotton and linen furnishing fabrics. Even the Scottish clan tartans have been featured in these fabrics, which have the advantage in price compared with woollen fabrics. A very suitable woollen fabric for upholstery is made from a two-fold yarn composed of Cheviot and Colonial Cross-bred wool. The cloth is well set up in the loom and is clear finished. It possesses excellent wearing properties, and is made in a range of styles from plain colours to fancy check and figured designs. The weaves in Fig. 5 A and B already referred to are very suitable, as they produce a very firm texture in addition to their utility for figure designing. Tweed curtains range from the thin open textures produced in gauze weaving with elaborate check patterns to the heavier types of plain and bordered fabrics.

I have tried to indicate as briefly as possible the principal features for development in fabric structures which have played such an important part in the Scottish Tweed Trade in recent years, and in common with other sections of the Textile Industry practically every avenue has been explored in an effort to secure novelty of structure, style and effect, which will appeal to Textile buyers all over the world. During the past few years manufacturers have experienced the most difficult times in the history of the trade, but we may feel reassured in the knowledge that when the long-looked-for trade revival comes we shall be prepared to meet it with a greater range of fabric structures than have ever before been utilised in the Scottish Woollen Industry.

SOME NEW POSSIBILITIES IN FANCY COLOUR AND WEAVE EFFECTS

By Professor A. T. KING, B.Sc., F.I.C.

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Before discussing the wool fabric effects with which this contribution is more particularly concerned, a few brief remarks may be permitted regarding production of novel effects in textile fabrics in general.

This, it need hardly be said, is a many-sided enterprise. While the designer's part is paramount in creating the basic novelty in appearance from weave effect alone, this would be very circumscribed were it not for the multiplicity of yarn characters, colour combinations, and finishing effects which can be variously superimposed on the design itself.

The variations made possible in this way, using only one kind of textile material, are of course further multiplied by incorporation of other materials in diverse manner.

Especially have we seen the development of the discovery of synthetic "silks" into important industries in consequence of their proved value in the above respects. Chemically very different from, but physically comparable with, the real article, the various rayons have further established themselves by the greater scope they offer for variety of finish, both on account of the inherently different nature of their filaments, and their different response to dyeing and finishing processes.

It is noteworthy that, in contrast with the active pursuit of modifications in these synthetic materials with a view to achieving new textile effects, relatively little has been done in this way with natural textile fibres.

Cotton has shown some adaptability in yielding commercially important modifications for example by mercerisation and acetylation, but wool and allied fibres have remained significantly without exploitation in chemical directions.

One may suggest two reasons for this. First, wool has a great tradition behind it. The industrial interests have been concerned to maintain its unique character and properties, so long regarded as being ideal for clothing material, and naturally have not looked with favour on any form of "mutilation" deliberately to achieve something different. This standpoint of letting well alone, the fear of anything happening to spoil its inherent properties, has served good purpose in preserving an unrivalled standard of excellence in wool fabrics, so that the term "all wool" carries an implication of quality hardly shared by other textiles.

Also it might with some reason be urged that such wide differences in type as are available in natural wools, are amply sufficient to give variety of manufactured product, and that to exploit wool which had artificially imposed characters would entail a reflection upon the real article, as "artificial silk" in the early days was held to have caused an adverse reflection upon real silk.

The rayons of to-day, however, suffer no "inferiority complex" of this sort, and no tradition binds them. Something "different" is hailed, other things being equal, as an advantage over other types rather than a retrogression, and there can be little doubt that the field of synthetic textiles is still largely unexplored, and that newer materials will appear on the scene and establish a place in the struggle for fabric novelty.

Secondly, wool, though in its natural state highly durable and capable of providing fabric of lasting wear, is in consequence both of its complex chemical constitution and its organised histological structure, peculiarly susceptible to certain disintegrating influences.

To make a very simple contrast, the corroded surface of a copper wire may be repeatedly removed, leaving a thinner but sound core beneath. Can we expect any parallel with wool fibre, with its discrete cell structures of outer cuticle plates enclosing longitudinally disposed spindle-shaped cortical cells, when the loosening of these structural units from each other, to say nothing of attack upon the molecular structure of the units themselves, could produce a weakening and disruptive effect out of all proportion to any obvious change in physical appearance.

Wool, therefore, presents peculiar obstacles against attempts to modify it into something of comparable yet distinctive utility. Nevertheless, in the writer's view, the rapid strides made of late towards elucidating its chemical constitution bring the day of *improving* wool for specific purposes and novelty effects measurably nearer. Success in this direction would mean no encroachment on the field at present held by wool. Rather would it expand its scope, not only by offering "new" textile materials for use in conjunction with other fibres, but also by extending the range of "all wool" fabrics.

"Unshrinkable" Wool Yarn

It is the writer's hope that such a prospect may be opened up by the new unshrinkable treatment which has already received reference, in the Press by the Wool Industries Research Association, and in a recent publication (A. T. King—"Some Observations regarding Unshrinkable Finish," *J. Soc. Chem. Ind.*, LIII (1934), p. 339). Devised in the first place to remove certain disabilities in the present chlorination process for rendering hosiery unshrinkable in washing—it may be noted that this involves the elimination of perhaps the most outstanding characteristic, i.e. the milling property of ordinary wool—subsequent developments suggest that it may provide a "new" fibre and yarn for textile novelty purposes.

The details of the actual process are not at present disclosable, but the main feature from the present standpoint is that uniform treatment can be given in loose wool or sliver form, the subsequent drawing and spinning further ensuring, in addition to genuine unshrinkability, the highest degree of levelness to dyeing. Incidentally the treated wool can be spun with at least equal facility. In fact definitely less twist is needed for a given count of equal strength as spun than is required with the untreated wool; and, conversely, greater nominal strength is obtained for yarn of the same twist and count. Also, it can be readily blended, roved, or two-folded with untreated wool, cotton, etc. for fancy yarn production.

Especially it would seem that unshrinkable yarn in bulk for warp and weft should offer a field in novelty fabrics, which though not new in suggestion so far as chlorinated yarn is concerned, has not hitherto been exploited as is now practicable with the new unshrinkable spun yarn.

Weave Effects

The object of this preliminary inquiry has been to utilise the unshrinkable property of the yarns to produce "blister" effects as a result of the shrinking of the ordinary yarn in scouring.

The figured patterns designed to this end by the writer's colleague, Mr. G. Priestley, have been produced mainly by means of double reversible fabrics, the warping being arranged one thread treated and one thread ordinary, with wefting also in the same order.

The weaves for these have been so arranged that a surface pattern of treated warp and weft, working in 2/2 hopsack, is produced, whilst behind this a corresponding detail is effected by crossing ordinary warp and weft.

The results of this method of structure clearly show the difference in the shrinking properties of the two types of yarns, for whereas the ordinary portions shrink during finishing in the usual way, the surfaces formed of treated yarn stand out owing to the "bunching" effect resulting from their inability to shrink, thereby giving an entirely new character to the surface of the fabric.

It may be further remarked that though different tensioning of ordinary yarn could give rise to somewhat similar effects, such fabric would continue to shrink with scouring, whereas the opposing effects of the treated and untreated yarns

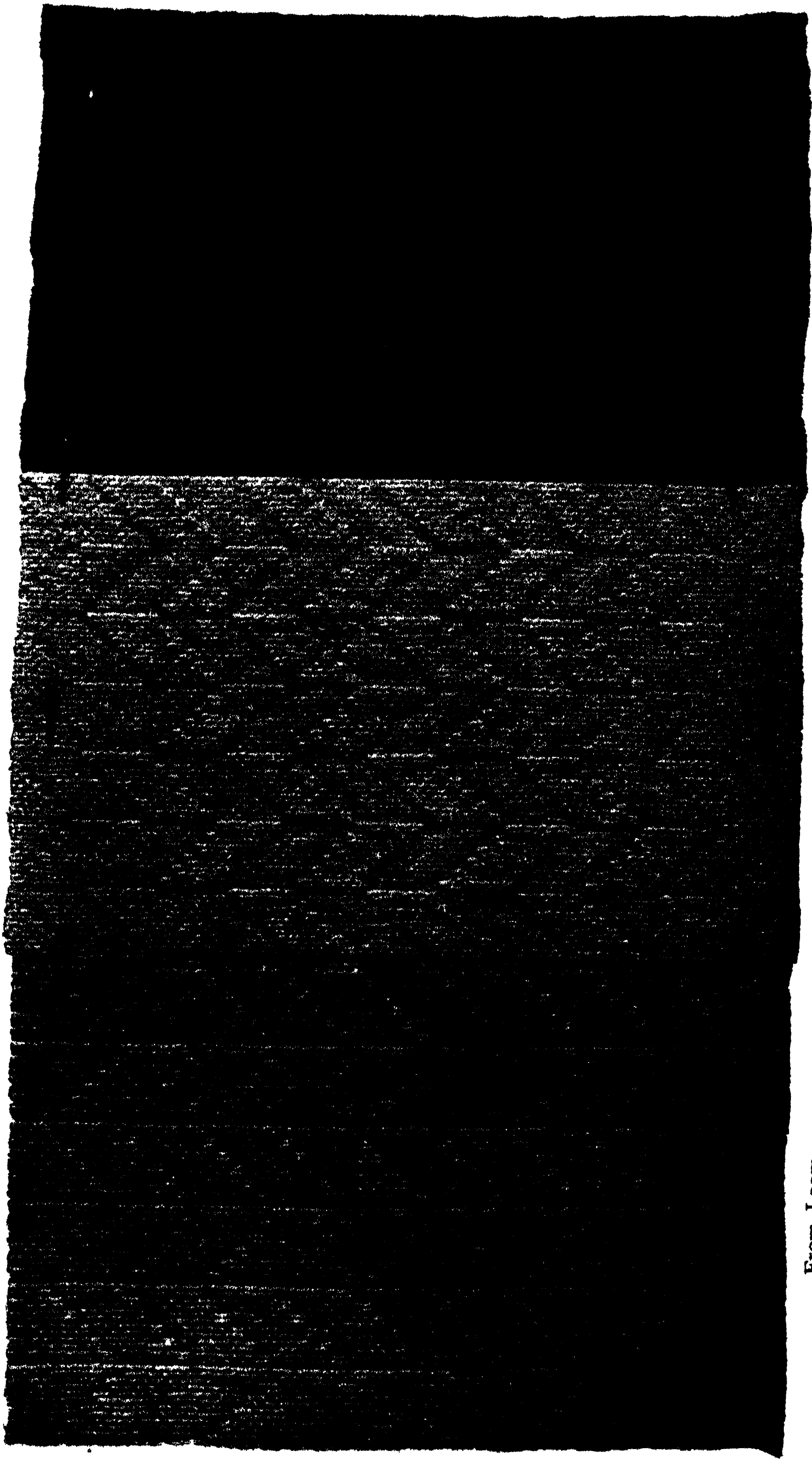

PLATE I

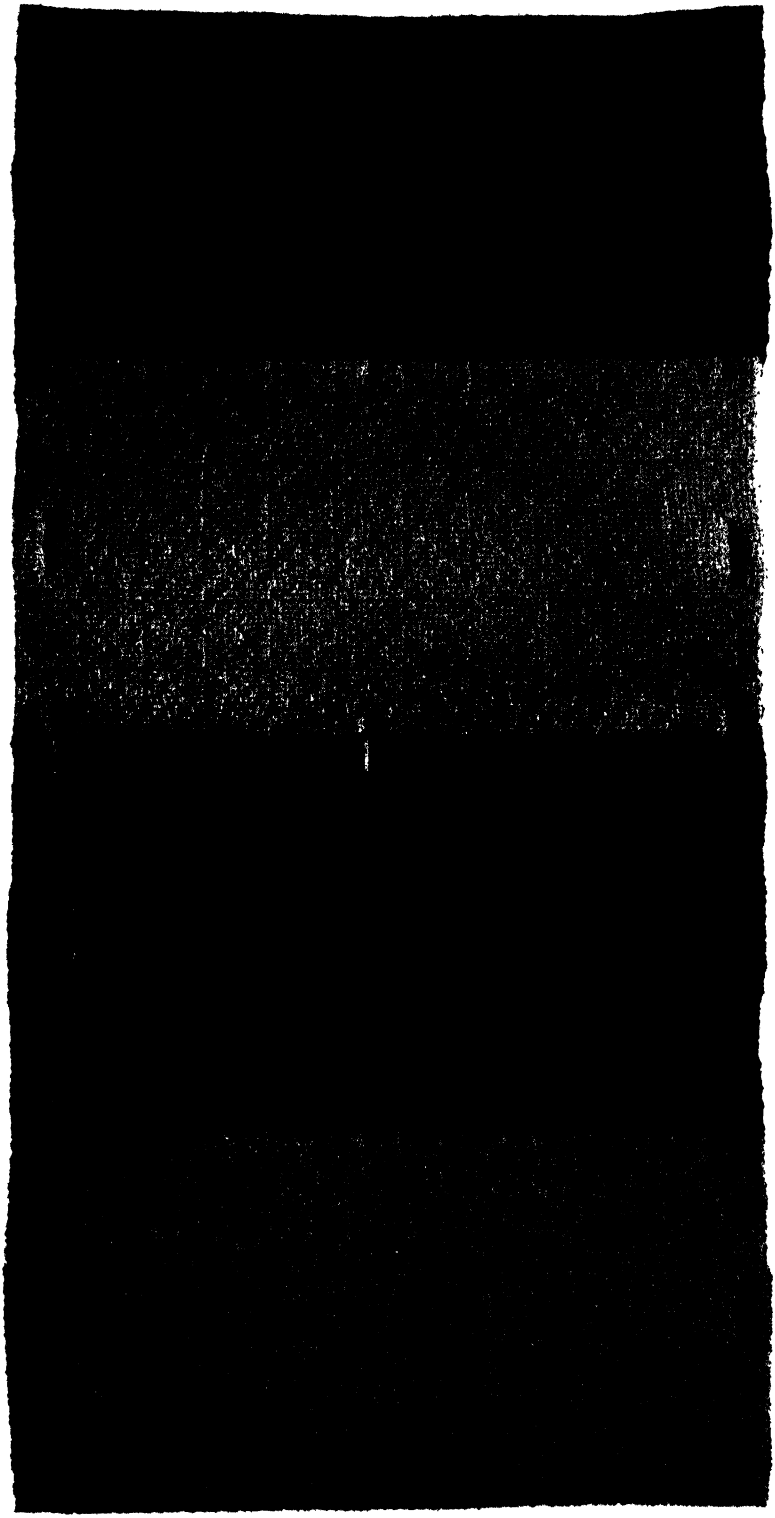

PLATE II

give a balanced structure which offers a resistance to further shrinkage on rescouring.

A typical example is shown in the photograph (three-quarter life size) of patterns before and after scouring. (See Plate I.)

Further samples illustrating this effect in various designs are also on view.

Colour Contrasts with Single Bath Dyeings

The field of possible novelty effects is further widened by utilising the different dyeing affinity exhibited by the treated yarns towards various dyestuffs. Preliminary experiments in collaboration with Mr. P. E. King show variations in result from a negligible difference in affinity with certain dyestuffs to very pronounced differences in shade between the two constituent yarns, especially with the Neolan colours.

The degrees of contrast obtainable are illustrated by Plate II which shows typical effects with the appropriate selection of dyestuffs, though these naturally do not convey the colour effects as shown by the actual dyeings on view.

A variety of two-colour effects can also be secured by using contrasting and level dyes in conjunction. Also, enhanced contrasts can be readily obtained by after-dyeing at lower temperatures, when the treated yarn absorbs the second colour almost exclusively and with reasonable fastness to washing.

The controlled application of dyes in this way is being further explored, but the examples shown will indicate the varied possibilities in this direction.

One point in particular may be worth noting, regarding pieces with a coloured striping thread, stored in the grey awaiting piece dyeing to the required colour. The choice of colours for the stripe thread, if made of the treated yarn, could with considerable latitude be left until the piece itself is dyed, instead of, as at present, having to be determined before weaving.

WARP-LOOM KNITTED FABRICS

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(University College, Nottingham)

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During the past decade there have been many far-reaching changes in the textile industry and warp-loom knitted fabrics have come to occupy an increasingly important place in our textile supplies.

A number of factors contributing to those changes may be enumerated, the first being the interesting position intermediate between the woven fabric on the one hand and the ordinary knitted fabric on the other. The warp-loom knitted fabric has warp threads but no horizontal series of weft threads, on the other hand those warp threads are intersected with each other in a looping or knitting process where knitting needles and looping elements are employed. For a long time this intermediate position appears to have retarded the fullest development of this industry, for the manufacturer of woven fabrics considered that it belonged to the knitted classification, whilst the hosiery manufacturer, accustomed to preparing complete garments for the market, felt that the handling of piece goods was not his province.

In recent times, however, many firms have taken up warp-loom fabrics in a special way and the use of these fabrics by the public has increased enormously. This has been an advantage because such firms have been enabled to develop the technique of these fabrics untrammelled by the tradition of either the weaving or the knitting branches of the textile industry. Another dominant factor has been the phenomenal progress registered by the engineer in effecting improvements in warp-looms which have greatly increased their productive capacity, gauge fineness and pattern scope.

SOME DETAILS OF PRODUCTION

The levers operating needle bars and sinker bars have been considerably shortened, giving more direct action and accurate working. The movements of these parts have also been given a curved action in place of a directly vertical or horizontal one, this having contributed further to smoothness of working. These machines are built as fine as 30 needles per inch, the spring-needle warp-loom being extensively used for the finest textures of locknit, tricot, and atlas fabrics, which have the usual marks of high textural quality associated with fabrics knitted by this type of needle. These machines are built up to 168 in. in needle width producing three widths of fabric 56 in. wide. Two machines are worked by one operator who is thus responsible for six double-width fabrics 56 in. wide each and at this width there are 220 courses per minute. When compared with the ordinary weaving loom, this shows remarkable productivity. The weaving loom is restricted fundamentally from being built to greater widths by the fact that the loom has to pause to allow the shuttle time in which to reach the other side. Thus increasing width causes correspondingly longer pauses and so retards production.

In the warp-loom, the main factor is the lapping of the threads over the needles which normally is one or two needle spaces, the time to effect those laps being but slightly reduced at the higher widths. The time required to make an ordinary lap at 168 in. of needles in width, is not appreciably more than that required for a similar lap for a fabric one quarter of this width. There are, of course, practical engineering difficulties which arise in producing looms at widths greater than the limits quoted, connected mainly with the usual variations in lengths of bars due to fluctuations in temperature.

The customary locknit is made with two bars, each having a similar but contrariwise action. The size of thread varies between 60 and 75 denier rayon counts in each bar. With a gauge of 28 needles per inch, the working would be from 30 courses per inch for a slack texture to 42 courses per inch for a stiff quality of fabric.

There are usually two beams for this fabric, the front beam having, for stiff quality fabrics, a length of 2,800 yards with 2,100 yards warped on the back beam. For the slack quality the back beam would require 2,500 yards and the front beam 3,000 yards. The warps are made in sections of 12 in. at a time. It is the essential feature of this structure that the two laps should be different, say one-and-one lap in one bar with two-and-one in the other. The direction of lap is contrariwise, to give a crossing of the threads, and this produces strength and firmness of texture. Each stitch then contains two threads, so that if one is broken or weak, the loop is held intact by the other thread and laddering is reduced to a marked extent. If both threads are fractured, the crossed threads in the fabric exert considerable control over each other, particularly in tight textures, so that running down is usually restricted to one or two stitches only. The warp-loom has benefited considerably by the development of rayon as these threads are smooth and are ideal for working in the fine apertures of warp loom guides. The guides are threaded by special threading bars having a number of drawing-in hooks to a section so that a corresponding number of threads are drawn-in simultaneously which enables 3,000 threads to be entered in little more than one hour. Another great advantage is the facility with which fabrics of any width can be produced side by side on the widest looms. Narrow fabrics of ribbon or girdle width are obtained with good selvedges by leaving several guides empty at the intervals required.

Warp-loom Texture

The warp-loom fabric has no weft, but the warp threads are knitted on each other and interlooped by the sidewise lapping of the threads and this signifies that both vertical and horizontal elements of the texture are obtained from the same warp threads. This laying of the warp threads round the needles consumes a considerable length of warp in relation to the length of fabric produced, for normal laps it requires four, five, or six yards of warp to produce one yard of fabric. With a warp of 3,000 yards and a take-up of six, there would be only 500 yards of cloth forthcoming. This is a matter of the greatest importance in planning lengths of web where two or more warps are used for different guide bars, as beams bearing different lengths are required to empty themselves about the same time. The weight of the warps employed for any fabric is, therefore, the weight of fabric produced, less any waste incurred, so that the fundamental costing of the fabric is readily obtained, when the cost per lb. of the yarns is known. The formula required is given as follows—

$$\frac{L \times T}{C \times B} = W$$

where L is the length of warp in yards, T the number of threads in the warp, C the counts, and B the basic length of the standard hank. By transposition the threads of any warp are obtainable as follows—

$$\frac{C \times B \times W}{L} = T$$

and the length similarly—

$$\frac{C \times B \times W}{T} = L$$

The cost of the warp with yarn at S shillings per lb. is $W \times S$, and the cost per yard where L_1 is the length of fabric produced is—

$$\frac{W \times S}{L_1} = \text{cost per yard of fabric.}$$

This is the cost due to materials only and if there are several warps in the same fabric, these are added together to obtain the resultant weight and cost.

In a plain knitted fabric there is considerably greater stretch in the width than in the length; on the other hand the strength is much greater in the length than in the width. The warp-loom knitted fabric texture appears to obey the same general law of setting as the ordinary knitted fabric, and similar fabrics on different needles per inch settings appear to vary inversely as the square root of the yarn counts in indirect systems.

$$G = k\sqrt{C},$$

where G is gauge in needles per inch, C the single counts in the worsted yarn system with the 560 yard hank standard and k varying with the type of fabric being manufactured. This formula requires to be modified in certain ways when change is made from woollen or cotton to rayon material as the latter has increased weight in relation to its bulk. That is, if a calculation figure of 300 deniers were to be obtained from woollen yarn of a similar texture, this would require to be reduced by about one-third, *i e.* 200 deniers to give the comparable cloth. Consequently in making a transfer from rayon to comparable wool or cotton, the counts obtained would require to be increased by about 50%, *i.e.* a calculation count of 30's would be 20's for an inverse system.

In correctly-set plain fabrics, the courses per inch vary between a 20% and 40% excess over the needles per inch for normal textures as these are required open or very tight and a similar law seems to apply to warp-loom fabrics. These are, however, more firm and stable than ordinary knitted goods, being generally stronger in the direction of the length than that of the width. Usually the stretch in the length is greater than that of the width, but in practice considerable variations occur. When the fabric is worked stiff on the needles with the yarns thick in relation to the setting or spacing, extremely firm and robust textures are obtained, capable of bearing a great breaking load and showing very little stretch. Two-bar fabrics having a double set of warp threads are extremely firm and whilst they have a lateral stretch, it is more in the nature of a spring which quickly recoils when the stretching force has been removed. During wear there is little tendency to bulge permanently if the fabric has been correctly set on the needles of the machine.

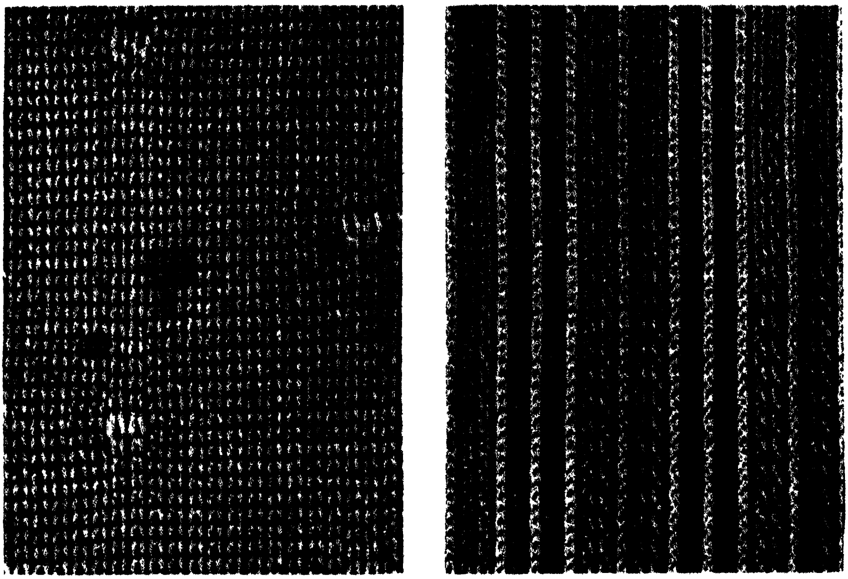
Modern Lustre Effects

With the increase in fineness of gauge to 30 needles per inch on spring needle warp-looms, quite different fabric properties are obtained. With fine deniers of rayon, fabrics weighing between 2·5 and 4 oz. per square yard are common, thus catering for the modern demand for fabrics light in weight and texture. With the evolution of these, a great change is apparent in the whole aspect of the fabric, ordinary laps and simple variations producing marked changes in the lustre qualities. The plain stitch alters in appearance as the mesh is made finer and this takes the form of a quite different quality of light reflection. Following the demand for excessive sheen in medium gauge rayon fabrics, the call is now for subdued sparkle or dull lustre and for types which show the light in minute fragments, as in those staple rayon yarns which are now being used. Perhaps the best-known lustre style is the shadow stripe which shows as a kind of herringbone effect due to the zig-zag type of pattern lap which may be regarded as the most characteristic type of warp-loom fabric. For a number of courses the loops are given a bias or angle towards the right and on reversal of the direction of lapping, the loops similarly exhibit a bias towards the left. In actual fact, these patterns are worked as a vertical zig-zag but when made into garments, they are turned so that the effect appears in a horizontal direction. An example of this is given in Fig. 1. These laps can, of course, be varied in size, or to give more fancy effects, may be composed of larger and smaller sizes of herringbone, with the proviso that the total number of leftwards laps must equal those which are rightwards. These effects may be compared with similar results of herringbone twills, the best known examples, largely utilised for intermediate garments, being in rayon or fabric with rayon face and cotton or woollen back. Part of the difference in lustre may be due to the angle of the twill running with the angle of yarn twist and against it in alternate ribs. Taking the woven technique as a parallel, these twills may be altered or varied in angle by increasing the size of the lap or move to two or three, instead of an ordinary progression of one. Satin, or areas of special lustre, may also be obtained by the use of larger laps, a two-and-one giving a much more lustrous appearance than one-and-one. Many attractive styles are also obtainable by interposing a single or several longer laps of four or five in the centre of a right or left herringbone which are similar to warp or weft ribbed stripes obtained in woven fabrics. But lustre effects may also be obtained by the use of tucked stitches where at selected points in a pattern certain stitches are left unknitted on the needles for one or two courses. Such elongated loops show in lustrous fragments as compared with the ground and can be arranged as spots or in any curved, diamond, or bayonet design form. Fig. 2 gives an alternate spot design worked on this system.

Recent Colour Designs

The various types of warp looms using single or multiple bars have a prolific means of producing remarkably rich and varied colour effects. These are in a category by themselves as possessing special characteristics of fabric structure and these effects have claimed a definite place in the textile markets of the world. They are less formal and correct in appearance than woven fabrics and may indeed show types of structure which in woven goods would be regarded as defective, but which are freely accepted for textile uses. The representation of colour patterns on squared paper is made with various symbols, full squares, dots, and dashes, which appear in progression according to the style of lap chosen. The colour order is made to move right or left according to pattern, with the proviso that the bar containing the threads must always return to its base within a reasonable period. In the case of an extensive lap to right, the fabric leaves the needles on the left one by one and occupies new needles on the right and *vice versa* when the direction of motion is reversed. This produces a sort of vandyke edge along each side which is often emphasised as a pattern feature in narrow fabrics such as scarves, but which for normal piece goods is regarded as a defect. To minimise this zig-zag selvedge, a separate series of threads working one-and-one plain lap from a separate bar are introduced as listings which give a straight appearance to each border. These large zig-zag laps combined with elaborate colour patterns in rich primary and secondary colours have a highly decorative value in ladies' garments and are in keen demand as trimmings for woven fabric costumes. These fabrics have made a valuable contribution to the enlivening of modern textiles, introducing an unexpected note of dash and sparkle into otherwise staid and formal costumes. Many of these effects occur in materials such as wool or cotton with rayon added in smaller quantities at specific points to act as a brightening agent for a dull-lustre ground. Rainbow-dyed yarns and graduated colour patterns are amongst the most striking examples of this type of design. In recent seasons, there has been a considerable demand for "tweed" effects, so-called, although many of these have a very remote resemblance to the fabrics produced on the Borders. This term has been applied to warp-loom patterns having a thoroughly melangé effect where the patterns do not proceed in a needle-by-needle orderly progression, but have a varied or irregular lap imparted to them. Fig. 3 illustrates a design of this type worked on the two-bar raschel warp-loom in woollen materials. The coloured threads are thereby mixed in effect, being moved forwards and backwards in a random sort of style so that they appear in minute forms like granite or oatmeal fragments. These have been developed ostensibly to imitate the usual styles of woven goods and they have met with an extraordinary good reception as resembling woollen and worsted fabrics, chiefly for ladies' costume wear. Latterly pin-stripe designs with hopsack and herringbone variations have been used to an increasing extent for ladies' blouses and men's shirtings. These are worked mainly in two genres of dull-lustre rayon, the fabrics being prepared as a pattern with acetate and viscose, with the designs developed by the usual methods of dyeing one and leaving the other ivory, or of dyeing two colours

FIG. 1



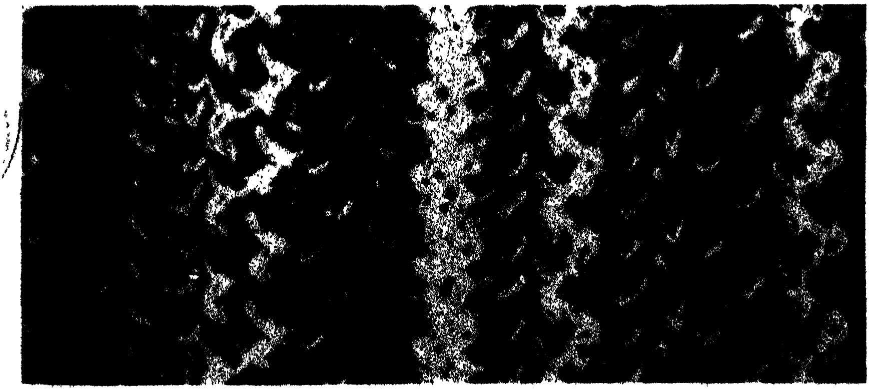


FIG. 3

PLATE I

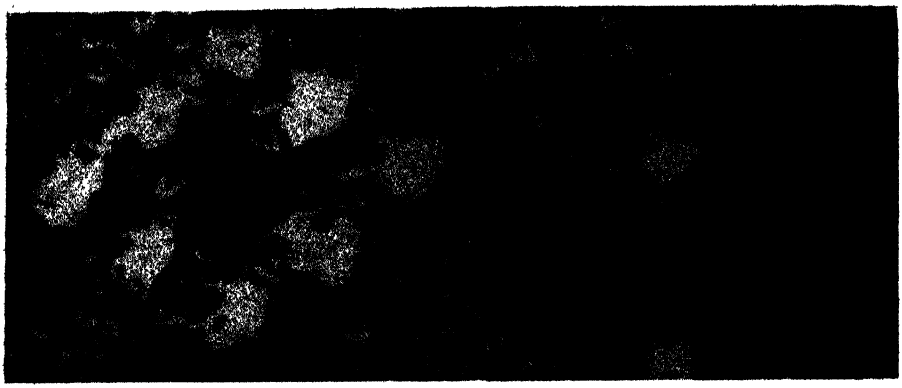


FIG. 6

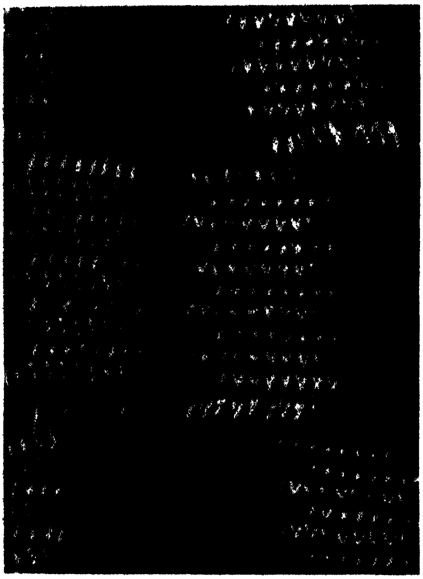


FIG. 5

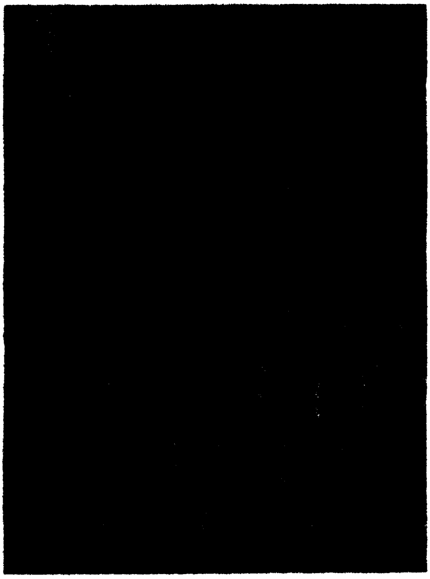


FIG. 7

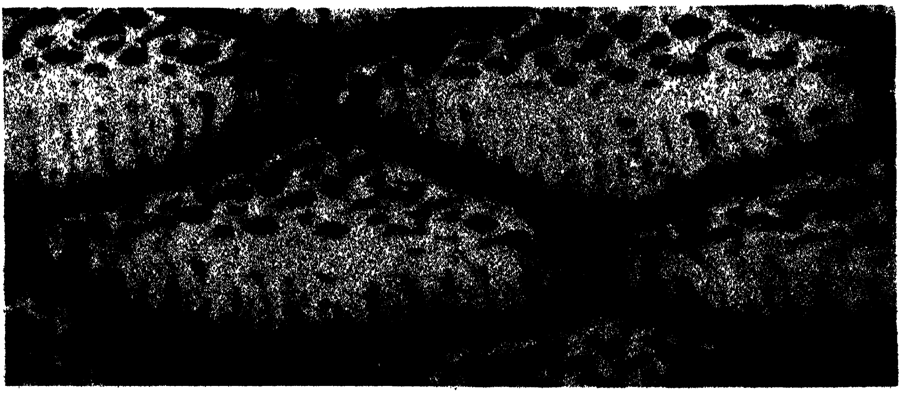


FIG. 8

PLATE II

in the same bath. The fabric shown in Fig. 4 illustrates this type of fabric in two varieties of rayon. This method has been adopted to an increasing extent to include woollen or cotton elements, as giving a most economical means of producing colour ranges of the widest and freest kinds, using the same patterns in white throughout, the colour range being developed by the dyer. The buyer is provided with a wide selection of colour suggestions and these are dyed from the white piece to the lengths required The warp loom can produce these in light weights for underwear, but employing two bars and a tighter and locked style of knit, firm and rigid textures of fuller handle and weight can be obtained suitable for most purposes of outerwear.

Two-bar Colour Effects

A most valuable range of colour effects are obtained by the use of two or more bars to which individual patterns or laps can be given and these lie at the basis of the valuable diamond patterns which can be so readily worked on the warp loom. The usual method is to have the same colour pattern in each of two bars and give them an identical lap but contrariwise; when the first bar is lapping towards the right, the second is lapping similarly towards the left and *vice versa*. This gives a thorough mixing of the various colours used as they interknit with each other in lapping to produce a resultant colour effect much more rich and varied than would be thought possible from the small number of colours employed. When bayonet zig-zag schemes and similar styles are worked on this principle, arched architectural effects are obtained which are most ornate and elaborate in appearance. Again these are often threaded in white or ivory so that one colour can be developed on the viscose and another on the acetate rayon in cross dyeing, or one of the elements may be left white and the other dyed to a colour. A typical example of this type is given in Fig. 5, cross dyed with one colour on the viscose and white acetate.

But there is no reason why the two bars should have an identical but opposite motion. The back bar can be altered in its starting position in relation to the front to obtain further patterns from the same warp threading. To create silhouette types of designs, two bars are threaded with many threads of colour A and colour B alternately and they are given a separate and distinct motion which corresponds to the contour of the figure which it is desired to produce. One bar moves to accord with the right side of the silhouette, and the other bar has a lap corresponding to the left side. This gives alternate figures, one developed in colour A alternating with one developed in colour B in the direction of the width.

Modern textile requirements have made full and ample use of the method of designing by the use of tuck pressers on spring needle warp-looms. In this category, more emphasis is laid on the nature of the surface of the fabric than on colour effect elaboration. By this means knop or raised effects are readily produced which give a kind of *bas relief* to the whole texture and also provide for a new genre of blending for coloured warp threads. By this principle, one set of needles are left unpressed so that they produce no loops, whilst the other portions knit and lap as usual, thus piling up mounds of stitches which erect themselves on the surface of the ground fabric as knops. The classic example of this principle of colour pattern is given in those pseudo Paisley shawl patterns where suitably bright primary, secondary, and rainbow colours with white are treated in this way. Accumulated stitches raise themselves on to the surface to form sharp peaks of material, these being in contrast with plain portions having a sparce loop distribution. A raised knop design in solid black and solid white is shown in Fig. 6.

Cellular Fabrics

The modern warp loom is admirably equipped for producing lightweight openwork and cellular textures which have proved such a feature of recent textile history. The public is coming more and more to appreciate the value of these cellular textures where a minimum of weight of material is employed in order to form a framework or skeleton in which pockets of air may be imprisoned. This is obtained mainly by half-threading in two bars, where alternate guides only are provided with threads. Each bar can form loops from its own threads for a few courses, then they move together and intermingle their threads to form the corners of the cells after which they move back to work in single limbs again. This method can be employed to produce many kinds of net fabrics in small close setting for general use, or in larger mesh for the production of nets and veiling fabrics. By leaving guides empty at longer and more varied interval any type of fabric or pattern can be punctured with these open spaces; the growth of this practice has greatly reduced the weight of two-bar fabrics and incidentally their cost and those spaces have also a high decorative pattern value. An example of this type of fabric is given in Fig. 7.

General

There are in addition many attachments which can be applied to the warp-loom to produce special fabrics. The jacquard has been adopted which makes a full and free selection of guides to produce any type of design no matter how elaborate. There is the attachment devised for producing the so-called elastic stitch which is specially suitable for hatbands. Specific methods or working technique have also been devised whereby the warp threads are given an extra pull after knitting to draw the fabric loops shorter and to enable them to exert a greater grip on each other as a preventative of laddering. There are also the valuable attachments for producing plush and pile fabrics on the warp-loom, and other arrangements whereby threads of weft are laid into the needles between the lapping courses to give fabrics of greater bulk and which have little or no stretch in the direction of the width or length, being as rigid as the firmest woven fabrics. There is also the wide range of fabrics produced on the loom having two needle bars, each of which is given a separate knitting motion to produce fabric resembling rib fabric and where double cloths can be produced being plain on one side with an elaborate colour pattern on the other, fabrics admirably suited for checkback and mantle cloths. Fig. 8 gives an example of a novel frill fabric worked on the raschel warp-loom where the two needle bars are set about $\frac{1}{2}$ in. apart. The effect is obtained by lapping one set of the threads over both needle beds so that they are drawn out in much greater length and they are secured by a series of chains in black which provide an attractive contrast with the white ground.

MODERN KNITTING STITCHES

By JOHN CHAMBERLAIN, F.T.I.
(Colleges of Art and Technology, Leicester)

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Hand-knitted Stitches

Specimens of hand knitting of the 5th Century A.D may be seen in the City of Leicester Museum. These were discovered in a tomb on the site of the town of Antinoe in Egypt. The art of knitting, however, was not introduced into Great Britain until the 15th Century A.D. Since that time hand knitting has been carried on as a home industry and as a welcome relaxation from modern turmoil and strife.

The basic stitches were originally produced by the aid of two thin rods known as knitting needles or pins. Even to-day many of the successful machine productions are but inferior copies of handcraft and at times the machine reproductions have a disastrous effect on the sales of hand-knitted articles as can be instanced in the case of the Fair Isle hand-knitted garments.

On the other hand many machine productions could not possibly be knitted by hand owing to their extreme fineness or to the fact that two or three threads are manipulated in different ways in the same stitch.

Crocheting

This is another form of looping carried out by the use of a small hook known as a crochet hook. As much finer threads are used than in knitting there is much greater scope for manipulative skill and patterning variation. The machine counterpart of this form of looping is known as warp knitting—the original basis of the production of machine-made lace—which permits of a corresponding increase in the variety of patterns producible.

Machine-knitted Stitches

As many of the modern machine-knitted stitches cannot be produced either by the aid of knitting pins or a crochet hook it is necessary to evolve a simple form of apparatus by the aid of which suitable research work may be achieved without resorting to the use of expensive machinery.

For this purpose a wooden or metal frame A should be constructed as shown in Fig. 1. This frame carries a number of upright rods B which are square in section at their lower ends and which carry cross pieces C at their upper ends to receive the loops. The rods must be removable because in the production of certain stitches, loops are meshed on both sides so that the rods are totally enclosed. The removal of the rods, however, leaves the fabric unimpaired. The loops are formed and meshed singly, the depth of the loop being obtained by placing the finger between two adjoining rods and passing the thread or threads underneath it. Initial loops may be made by passing a thread over three of the cross pieces to the right and back under two cross pieces to the left. Subsequent loops are made by passing the thread in front of or at the rear of these loops, as desired; the original loops are then passed over the new loops. A single thread may be used and the knitting may be carried out laterally for "weft" knitting or two or more threads, disposed in various ways, for "plated" work. The loops may be manipulated in any desired manner, *e.g.* accumulated for tuck work; threads passed under the cross pieces for "float-stitch"; and loops transferred etc. for open work. To produce warp knitted stitches, one or more threads must be used for each rod.

The apparatus may be elaborated by using two parallel rows of rods, the cross pieces being placed either alternately or in line.

CLASSIFICATION OF MACHINE-KNITTED STITCHES

There are two broad principles of knitting, viz. lateral and longitudinal. The former may be flat selvedged or tubular, but, if produced on a circular machine, there is a course spiral the angle of which can be found from the following equation—

Let $N =$ Number of feeders
$C =$ Courses per inch
$D =$ Width of single fabric in inches.

$$\text{then } \operatorname{Tan} \theta = \frac{N}{CD}$$

For maximum cover, the length of yarn in a single stitch must not exceed $\frac{3\pi + 2\sqrt{13}}{4}$ times the wale width. If a longer length is used the needle and sinker loops lie apart. Lateral knitting is known as plain knitting, framework knitting, and "course" knitting. Selvedged knitting is sometimes called flat knitting or weft knitting. The terms stockinette and Balbriggan are applied to fine fabrics and "sham-knit" and shaker fabric to coarse fabrics. One well-known firm uses the French term "tricot" which, however, has been applied to a type of longitudinal knitting. Other terms refer specifically to the materials used or to some modification of the stitch contour, *e.g.* rayon fabric, crêpe, etc.

Longitudinal knitting necessitates the employment of a number of threads equal to or exceeding the number of wales in the fabric width. It is generally called warp knitting but sometimes "wale" knitting.

There are three basic stitches in lateral and spiral knitting, viz.—

Plain—In which all loops are meshed on the same side.

Rib—In which longitudinal chains of loops or wales are meshed on opposite sides.

Purl—In which lateral rows or courses are meshed on opposite sides.

Rib and purl stitches may be expressed numerically, *e.g.* 1 × 1 purl, 2 × 2 rib, or if a number of combinations occur in the same fabric the terms fancy or jacquard may be used.

MODIFICATIONS OF THE BASIC STITCHES

As this is strictly a technical treatise, loose terms such as are often used in the trade are avoided and those given apply definitely to variations in stitch forming. A "lace" fabric may be knitted as a needle or sinker loop transfer stitch, a tuck stitch, dropstitch, or warp stitch. Interlock is a double rib stitch. The law courts alone could decide what is "jacquard" knitting, as a given pattern might be obtained by means of jacquard cards or by many other forms of selecting mechanism.

The following list gives the fundamental variations.

Plated Knitting—In this variation two or more yarns are used at each "feeder", *i.e.* knitting point, and the fabric consists of two or more layers which are intermeshed collectively. This fabric can be compared with the plating of metallic surfaces. It should not be confused with "plaiting" or "platting" which is carried out on quite a different principle.

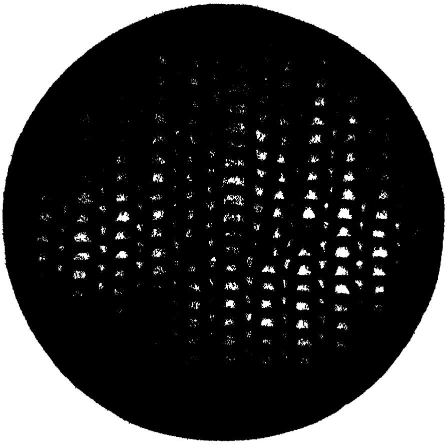
Reverse Plating—In this case the yarns are selected in regard to position as desired to form a design, both yarns knitting continually.

Drop Stitch—In this type of knitting the loop is formed but not meshed and in plain fabric causes a defect known as laddering (see Photo-micrograph 13).

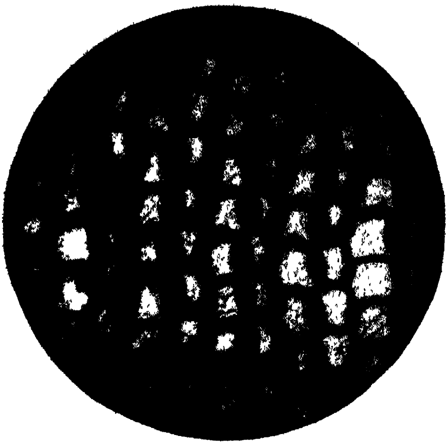
Float Stitch—This is produced when loops are knitted at intervals only and connected by straight threads known as "floats".

Float Plating—In this stitch two or more yarns are employed at each feeder as in plating but the face yarn is floated where required to produce coloured effects or open work.

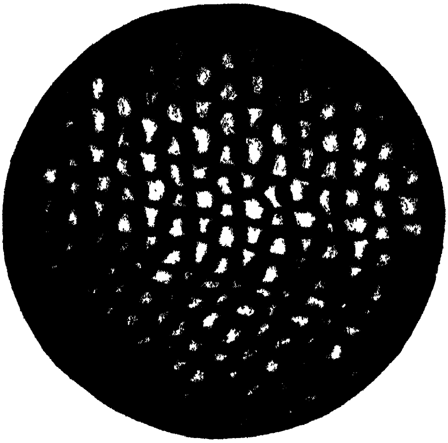
Held Stitch—This is a loop which is prevented from intermeshing for one or more courses, and may be held for a number of courses without any other stitch behind it or the stitches behind it may be floated or tucked.



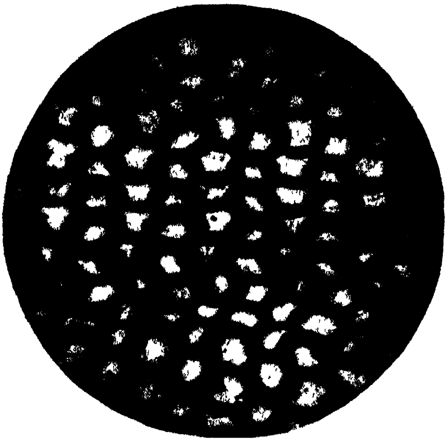
1—Fine Gauge Knitting (showing ladder).



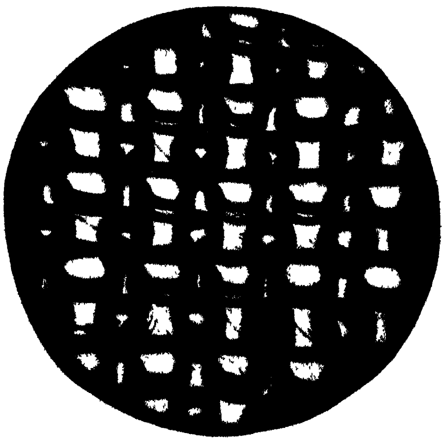
2—Irregular Knitting (yarn variation).



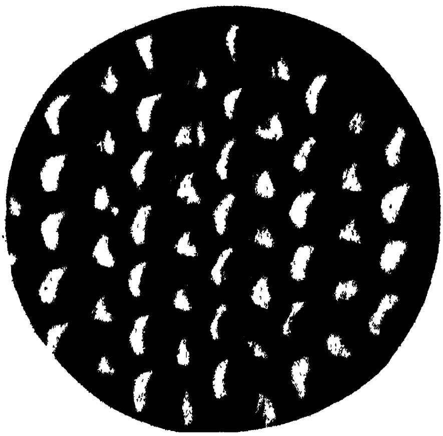
-Plain Knitting with wale spiral.



4—Plain Knitting Crêpe effect.

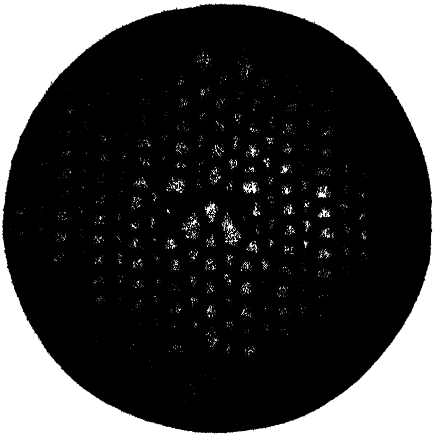


5—Ladder-resist Binding Stitch (Mills' patent).

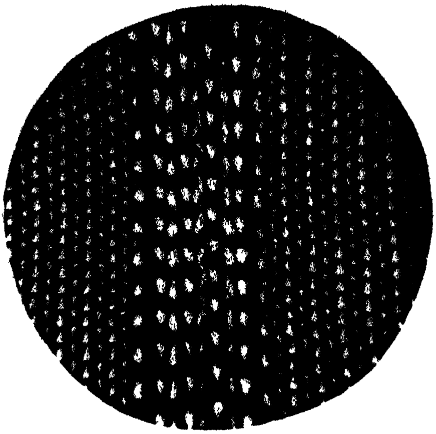


6—Ladderproof Knitting Wale-lock (Wildt's patent).

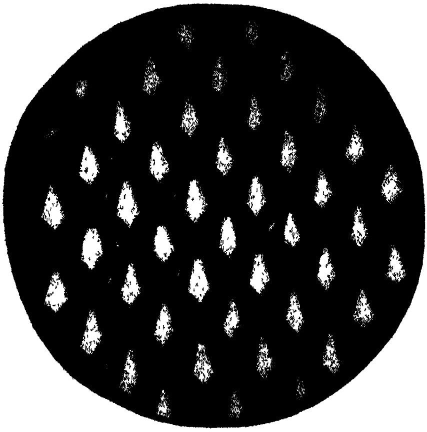
Plate I



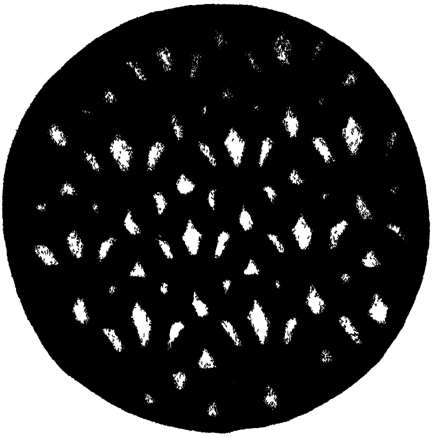
7—Isolated Tuck Stitches.



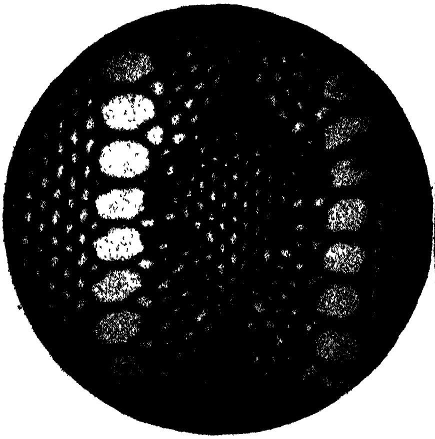
8—Satin Stripe (Tuck Loops).



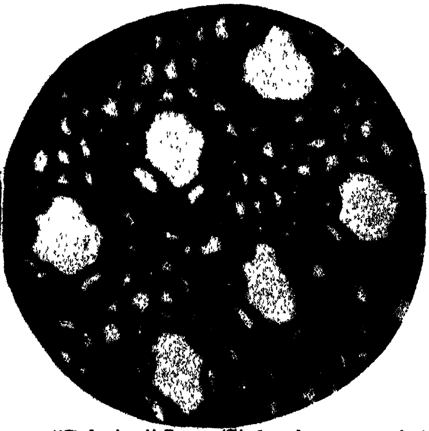
9—1 × 1 Alternate Float Stitch.



10—Circular "Locknit" (1 × 1 Float and Plain Knitting).

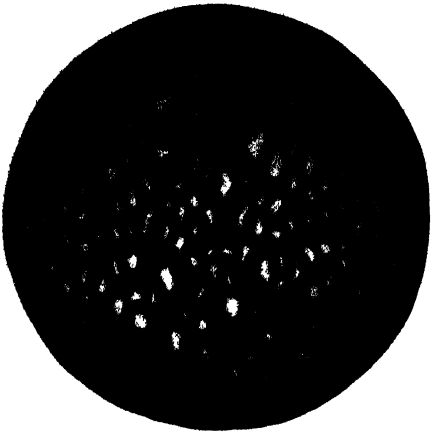


11—Lace Clock Transfer Stitch.

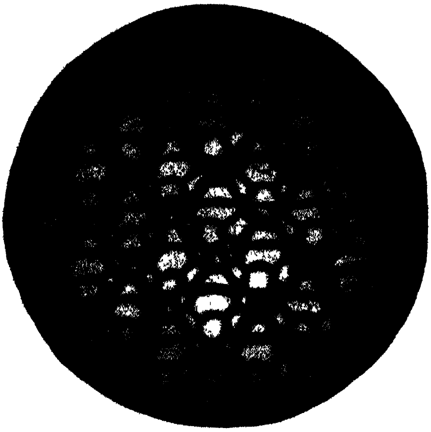


12—"Pelerine" Lace (Sinker loop transfer).

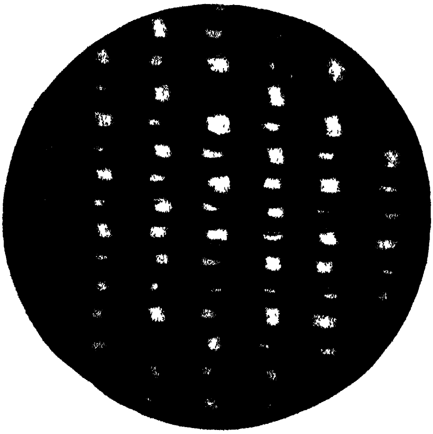
PLATE II



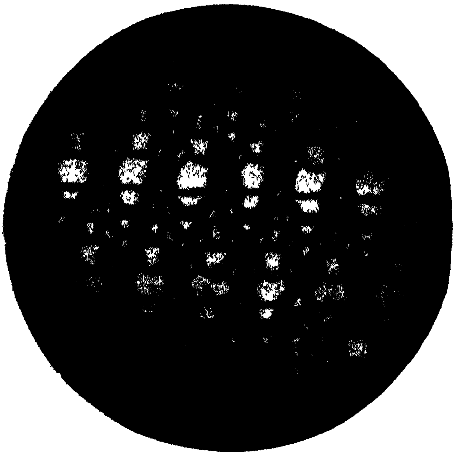
13—Crêpe Fabric
(Intermittent Tuck Stitches.



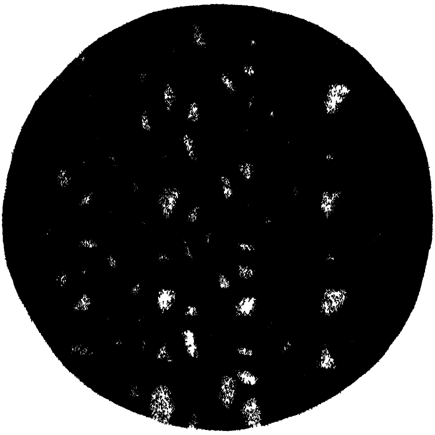
14—Open Mesh or Fish Net
(Float-plating).



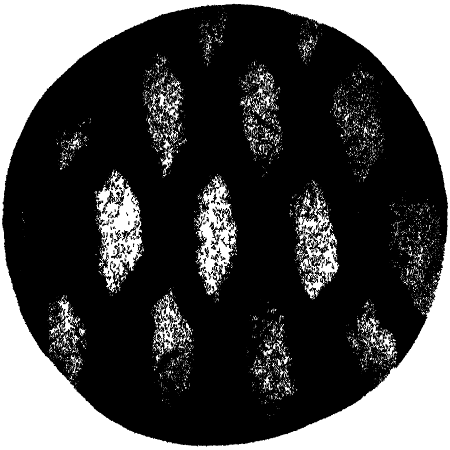
–Modified Interlock Fabric
(extended).



16—4-Course Fish Net (Float-plating).



17—Tuck Interlock.



18—Warp Lace (Pillar Net).

PLATE III

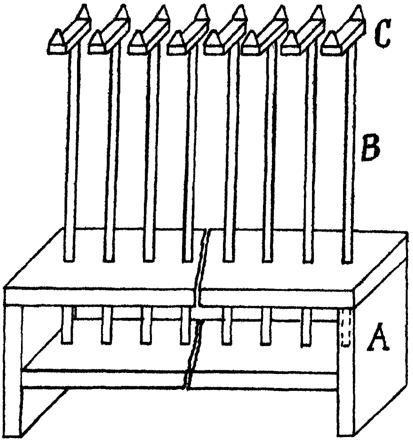


FIG. 1—Experimental Looping Frame.

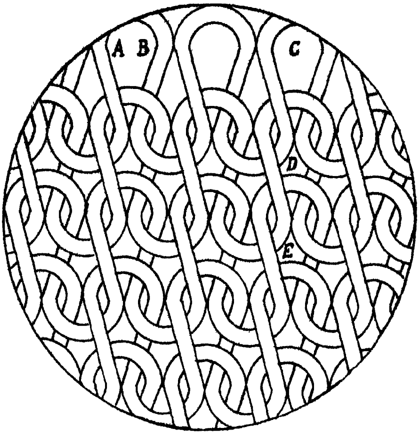


FIG. 2—"Through and Through" Stitch.

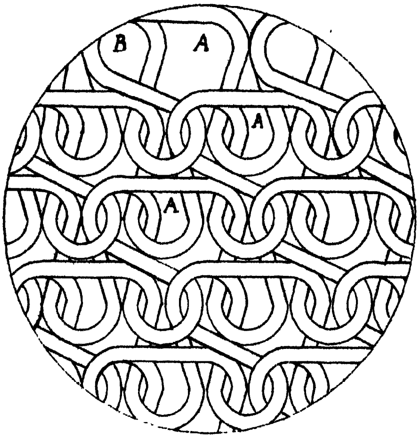


FIG. 3—"Half-transfer" Stitch.

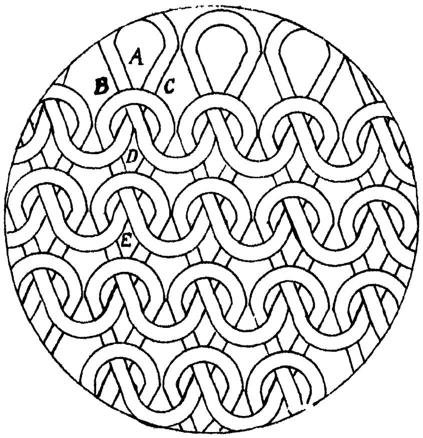


FIG. 4—Twisted Loop Stitch.

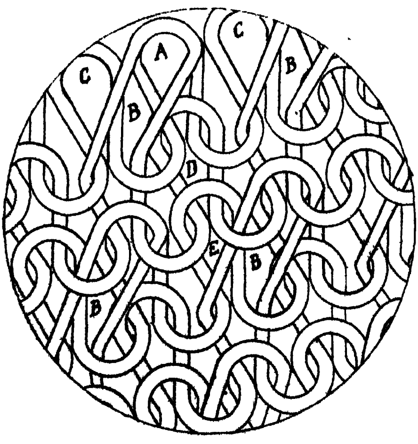


FIG. 5—"Pick-up Transfer" Stitch.

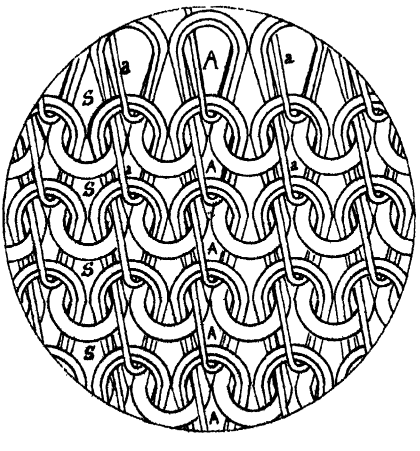


FIG. 6—Wale-lock (Ladderproof Stitch).

Tuck Stitch—The loops formed behind the held stitch and not meshed for one or more courses are known as tuck stitches.

Accordion Stitch—A combination of tuck and float stitches in a 1 × 1 formation to prevent long floats.

Transferred Stitches—The meshing of two or more adjoining loops with one or more loops at the next course. Loops may be either all needle loops or needle and sinker loops.

Shogged or Racked Stitches—Stitches, the sides of which are inclined or stitches arranged diagonally or in chevron formation. This effect is produced on rib fabric by racking one series of needles.

Fleecy Stitches—Long loops formed at the back of the fabric to serve as a lining or to produce raised effects as face threads. In some cases the loops are subsequently brushed to form a fleece.

Plush Loops—Comparatively short loops, cut or uncut, knitted at the back of the fabric to produce plush effects.

Twisted Loops—Loops having crossed longitudinal components to form closed loops (see Fig. 4).

Embroidery Stitches—A form of plating in which the ground fabric is ornamented by the knitting of longitudinal loops in a prescribed order on the face of the ground loops.

Straight Weft Effects—Straight unknitted weft threads, elastic or non-elastic are enclosed by or incorporated with the knitted ground.

Straight Warp and Weft Effects—A combination of knitting and weaving.

Most of these variations can also be produced in connection with longitudinal or warp knitting although in many cases the nomenclature used differs from the terms given.

Comparison of Terms Used for Similar Variations in Lateral and Longitudinal Knitting

Lateral or Weft Knitting Terms	Corresponding Terms in Warp Knitting
Plating	Double bar fabric (two series of warps)
Float-stitch	Lateral float or "swinging" (longitudinal float)
Float-plating	Fall-plate work or gimping
Held Stitch	Shell designs and ripple effects
Tuck Stitch	Knock-off laps or isolated tucks
Shogged or Racked Stitches	Vandyke or traverse designs
Fleecy Stitches	Backed fabrics
Plush Loops	Plush
Embroidery Loops	Superimposed effects
Straight Weft	Weft effects
Other Common Terms	**Warp Knitted Equivalent**
Interlock	Double rib or Raschel fabric
Lace (transferred loop, tuck, etc.)	Lace (non-contact of wales), nets
Knop Designs	Crêpe effects
Knitted Tweed (tuck etc.) ...	Warp knitted tweeds (variable laps)

MODERN STITCH DEVELOPMENTS

The rate of production of the basic stitches is hardly likely to increase materially until some new method of knitting has been devised. Finer fabrics may still be possible but as a pair of fine silk hose already contains over half a million stitches it is obvious that the limit is not far off. Fabric photo-micrograph 1 shows the sheerness and regularity of a fine silk fabric marred by the presence of a run-down stitch or "ladder" which extends half way down the middle wale. Photo-micrograph 2 shows by way of contrast a much coarser cotton fabric knitted from a very irregular yarn. Photo-micrograph 3 shows the variation in knitting properties of different yarns. The upper straight portion has been knitted from an ordinary American cotton yarn and the lower part from a wiry worsted possessing more twist, which results in a wale inclination of nearly 45°. Photo-micrograph 4 shows how attempts have been made to commercialise a defect by using yarns having varying degrees of right and left-hand twist to obtain a crêpe effect. Photo-micrograph 5 shows the Mills ladder resist fabric which is produced by the use of tandem-latch needles, the binding yarn being fed between the latches and retained whilst the previous loop is meshed with the succeeding loop. Photo-micrograph 6 shows a fabric which is ladder-proof, the construction of which will be explained later. A higher magnification has been used to show the locking stitches more clearly.

Modern Uses of Tuck Stitches

Photo-micrograph 7 shows a use of the principle of tucking to produce a fashion mark on a fine silk seamless hose. This, however, is readily distinguishable from the true transfer owing to the presence of the held stitch which, as shown, is elongated. Photo-micrograph 8 shows how lustre effects are obtained, when knitting with rayon yarns, by using a longitudinal formation of tuck stitches. As tucking takes place on alternate needles at every other course the held stitches are elongated to double length as shown and the lustre is correspondinglyincreased by reason of the reduced number of face courses. Any width of stripe may be made and the fabric is known as satin stripe. The tuck stitch is now employed to form raised effects by using a large number of successive tucks as well as imitation lace effects and designs in colour and in stitch and colour (examples of these will be found in the fabric exhibits).

Photo-micrograph 9 shows an example of float-stitch made on a very fine gauge machine Floats occur on odd wales at alternate courses and even wales at the remaining courses. The fabric is known as "twilsheen".

Another modern development of the float stitch is shown in photo-micrograph 10 which features a ladder-resist stitch known as "locknit". Floats are made at alternate courses over odd and even needles respectively, the intervening courses being plain knitting.

Effects of Transferring Stitches

Stitch transfer forms the basis of a large number of designs, *e.g.* raised effects, knop rib designs, lace, etc , and is also used for fashioning purposes.

Photo-micrograph 11 shows part of an openwork clock of a silk hose. As loops are transferred at alternate courses a lace-like effect is produced, whilst by varying the number of loops transferred a raised pattern effect is produced simultaneously.

Photo-micrograph 12 shows a modern development of the pelerine stitch, *i.e.* a sinker loop transferred to the needles. Formerly a course of long loops was made and certain of these loops transferred to the needles. The present development consists of making elongated loops at those places only where loops are to be transferred. The loops may be transferred to a single needle or the loop placed round two adjoining needles as shown in the illustration. Two or more loops may be retained and transferred collectively to form larger openings. By these means, all-over cellular fabrics are produced or patterning mechanism is employed to form openwork designs.

Crêpe Fabrics

The term crêpe does not indicate the stitch principle but the fabric appearance. An example has previously been given of a crêpe effect being obtained by using different directions and degrees of twist in yarn Crêpe is also a term used for fabrics of a warp-knitted character where loops are held on one needle bar and knitting continues on the other. The modern crêpe fabrics produced from rayon yarns are mainly irregular tuck fabrics in which the repeat is not discernible. Photo-micrograph 13 shows a typical example of tucking over one or two wales at irregular intervals with irregular spacings. This has the effect of breaking up the wale regularity and decreases the lustre due to directional light reflection.

Float-plated Fabrics

The original idea of float-plating was to obscure the face loop by floating it at the back of the fabric and coloured designs are produced on this principle.

It was subsequently observed, however, that the float-plating on alternate needles produced an open effect and advantage was taken of this feature to produce open-mesh or "fish-net" hose. Photomicrograph 14 shows an example of two-course 1 × 1 float-stitch which floats the face yarn on alternate needles at every other course, the remaining courses being plain knitting. As this fabric can be knitted on seamless hose machines as quickly as plain knitting, it has been largely used for the summer trade. It is a ladder-resist fabric but the elasticity is not equal to that of plain knitting. Underneath photo-micrograph 14 is another, photo-micrograph 16, of a four-course float-plating stitch which produces a larger mesh opening, three successive floats on the odd needles are followed by one course of plain knitting after which three floats occur on the even needles followed by one plain course.

Warp Lace Fabrics

For comparative purposes photo-micrograph 18 show how still larger openings can be produced by warp kintting on a principle of continued non-contact of the adjoining wales. Two half sets of warps are used and pillar on needles 1, 2—3, 4—5, 6 forming crossed chains, after which pillars are formed on needles 2, 3—4, 5—6, 7. The longer the pillars the larger the openings when the fabric is stretched laterally.

Interlock Fabrics

Normal interlock fabric is a double intermeshed 1 × 1 rib fabric. The needles are directly opposed and knitting takes place on even cylinder needles and odd dial needles at one feeder and on odd cylinder needles and even dial needles at the next feeder The chief virtue of the fabric is that both surfaces, being composed of face loops, are smooth, thus preventing irritation. The popularity of the fabric has led to certain stitch variations being made as with other types of knitting. Photo-micrograph 15 shows a modified rayon interlock fabric extended to show its double-rib construction, whilst photo-micrograph 17 shows a tuck interlock effect. Unfortunately stitch variations in interlock destroy the surface smoothness, hence all that can be claimed is fabric variation on one or both sides.

Ladderproof Stitches

The popular clamour for ladder-proof fabrics continues unabated but it must be borne in mind that other properties are essential especially in the production of hose. Many warp-knitted fabrics are definitely ladderproof such as "half-tricot", *i.e.* combined 1 × 1 and 2 × 1 laps now almost universally known as "lock-nit", milanese, etc. Unfortunately these are not only piece fabrics but are deficient in true elasticity. Consequently whilst they are ideal for lingerie, dresses, etc., they are not suitable for hose, although possessing the desirable property of being ladderproof. For hose true elasticity is required as a snug fit is essential and many attempts have been made to produce fabrics combining the two special features needed. Several fabrics such as ordinary plated fabrics, fish net, pelerine, resist laddering to a moderate degree and are often sold and guaranteed as ladderproof.

Fig. 2 shows a loop drawing of an ideal fabric which unfortunately it is impossible to produce on a machine-knitted basis. It has the elasticity of plain knitting but in order to produce this fabric a single yarn must be passed through each loop twice, once from the front and then from the rear as shown at A, B. Its ladderproof qualities will easily be understood by assuming the loop C to be severed. The loop D underneath C, in the same wale, would then simply fall on the loop E and no laddering would occur.

Fig. 3 shows a loop drawing of a very old partial transfer stitch previously used for size marking and for openwork web. It is produced by placing the loop A over the adjoining needle at B without completely transferring it in the normal manner and is thus known as the "half-transfer" stitch. The loop A, if severed, will permit the loop underneath in the same wale to drop, but as this is followed by another loop A, and the latter is held on the adjoining wale no further laddering occurs. The elasticity is slightly reduced as the sinker wale between the loops A and B is only held on one side and consequently when stretched is permanently changed in form. This stitch has been patented in the U.S.A. as a ladderproof stitch for the manufacture of full-fashioned hose.

Fig. 4 shows another old stitch the existence of which has almost been forgotten. It can be produced on special machines of the "Terrot" type and is known as the twisted loop stitch, being formerly used for the production of underwear. It will be seen that the sides B and C of the loop A are crossed and hence exert frictional resistance to laddering. Thus if loop A was severed, loop D would not run down as readily as an open loop and this would apply to loop E and subsequent loops in the same wale. Unfortunately it would be very difficult to produce on hose machines and other ladderproof fabrics are available for lingerie.

Fig. 5 shows a loop drawing of a fabric also patented in the U.S.A. which is a development of the "pick-up" stitch transfer used for many years in the widening of selvedged fabrics. Alternate loops B are picked up and placed on adjoining needles at A after a course has been knitted whilst the loops A and C are undisturbed. Subsequently loops A and B are meshed together. After a plain course has been knitted, loops on the other needles are picked up and transferred as shown. If loop A is severed, loops D and E run down but no further laddering takes place. If loop B is severed, three loops can ladder but no further laddering can take place.

Fig. 6 shows another method of obtaining a ladderproof effect in this case on seamless hose. The ground is ordinary plain knitting the elasticity of which is left unimpaired. At the back of each wale is a warp chain A which produces a wale lock and prevents laddering. The face of the fabric cannot be distinguished from plain knitting and the warp chain is only slightly visible, under close examination, at (*a*). The sinker wales S are not affected by the chaining (see photomicrograph 6). Fine real silk wale threads are used, mostly two-strand, although one-strand has been used. Silk or rayon may be used for the ground thread and the hose has all the modern features of the seamless variety. The wale threads are rendered inoperative during heel and toe knitting. The other well-known ladder-resist fabric illustrated in photomicrograph 5 is also used both for the manufacture of seamless hose and fabric and possesses excellent qualities.

Research in ladderproof stitches is still being carried on and the present fabrics are being improved both in texture and in rapidity of production as well as in the methods of application. Enough has been said to illustrate the remarkable developments in knitted stitches and the exhibit of fabrics, fabric photographs, and photo-micrographs will reveal the extent of the work done. Progress is essential if the present uses of knitted fabrics are to be maintained as fashion demands new types of fabrics, new stitch formations, and the remedying of minor defects discovered by wear alone. Fortunately British machine builders are very alert, spend money on research, are constantly increasing the patterning scope as well as speeding up and simplifying the various types of machines. There is a certain fascination connected with the possibilities of knitting, but there are also many pitfalls and a close search of the class 74 patents is advisable before carrying out experiments in certain directions. Moreover it is essential to study the properties of the various stitches before building expensive machines for their production. Hose, half-hose, socks, lingerie, outer wear, gloves, etc., require fabrics possessing special characteristics and it must not be assumed that a single fabric has all the necessary properties for the manufacture of all of these articles. Fabrics differ greatly in length and width elasticity, in resistance to crushing, creasing and wear, in bulk, handle and feel as well as in appearance. Scientific data is almost unknown and the manufacture of knitted goods still remains more of an art or craft than a science.

FABRIC STRUCTURE AND LAUNDERABILITY

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One of the aspects of design in fabrics is that their structure shall be suited to their purpose, particularly in respect of wear. Naturally there are many different kinds of wear to which different fabrics are subjected, but all of them must experience a common condition in course of time; that of becoming soiled. In many cases the soiling is a slow process and is such that it does not seriously affect the use to which the fabric is put, in other cases soiling is rapid or of such a nature as to hinder the proper use or enjoyment of the fabric after a very short time. Whether the one or the other, it is inevitable that after some period a cleansing of the fabric is either desirable or necessary, and in consequence it seems of importance that textiles of all natures should be considered in relation to a cleansing process. This is particularly so of those fabrics which become very rapidly soiled in use, for in their case the cleansing treatment must be repeated frequently if they are to be maintained in useful condition; the only alternative is complete replacement.

In view, therefore, of the inevitable application of a cleansing process, frequent or otherwise, to the vast majority of fabrics in use in modern times, the user surely wishes to be certain that any particular textile material is capable of being cleansed, and he who has to cleanse it also desires information upon how he may do so with success. Both of these attitudes require some co-operation from the designer and manufacturer of the fabric who should himself surely recognise that his products are destined to pass through cleansing processes and should make provision accordingly.

The purpose of this paper is to attempt to show that there is need for greater co-operation between fabric manufacturer and launderer, in order that by free interchange of information the materials produced by the one and cleansed frequently by the other may be satisfactory in every respect to the user as far as it is possible to make them so. The title of this paper employs a word which is not to be found in any standard dictionary of the language but it is one which of late years has become urgently needed. Only by cumbrous circumlocution can the fact that a fabric is "launderable" be expressed. It is insufficient to rely upon the word "washable" as that has come to be applied more especially in relation to the behaviour of dyestuffs in normal washing. Laundering is, however, not merely washing; it necessarily includes also processes of dressing and finishing, all carried out in a particular manner, and all having some effect upon the fabrics laundered. The "launderability" of a fabric is, therefore, its suitability for the whole process of laundering, as carried out by recognised and proper methods.

It is as well to sketch at the outset some of the principles of modern methods of laundering; greater detail will be found in a paper previously published (*J.T.I.*, 1934, XXV, p. 24). Excluding methods of dry cleaning, with which I am not directly concerned, all cleansing methods rely upon the use of aqueous solutions of detergents in which fabrics to be cleaned are agitated for some period of time, and make use of temperatures which may range from cold to the boil. There is to-day more than one class of detergent materials available, but except for special purposes where greater expense is justifiable, soap is that most commonly used, in conjunction with an alkali which may be of one kind or another according to the kind of fabric being washed and the needs of the process in its power of removing soiling matter. Flexibility of control to meet these two requirements is now further obtainable by the use of sulphonated fatty alcohols and similar bodies so that it is not uncommon to find laundry processes employing alkalinities lying in the range of *p*H5 to *p*H13.

Besides the actual detergents, a bleaching material may be used in cases where the removal of stains is necessary, and as a rule a hypochlorite bleach is employed for this purpose. Further material requirements are covered almost entirely by starch, in one form or another, and a blue which may be used to render the resulting white of the work more pleasing to the eye.

The materials which are used in modern laundry processes are of themselves unable to effect sufficiently rapid cleansing and they must be assisted by the provision of mechanical agitation. From the point of view of fabric structure this mechanical side of the laundering process is probably the most important. There is no need to describe here the action of the ordinarily used laundry washing machine; that has been done in the paper previously cited, but the complete washing and rinsing treatment which is required to cleanse white work in the modern laundry necessarily subjects the fabrics to the tumbling and rubbing action of the rotary washing machine for about 1 hour. The degree of rubbing is to a large extent under control. It can be increased or decreased in intensity within limits where there is special need, and in well-controlled laundries every effort is now being made to keep it as low as possible. It still remains a fact, however, that if fabrics are to be satisfactorily cleansed they must be subjected to mechanical motion and that for some period of time.

In the drying and finishing of laundered work there is little that can seriously affect the condition of the fabrics if the processes are properly controlled. The bulk of the water is removed by a centrifugal hydro-extractor (which exerts no mechanical strain upon fabrics if they are correctly packed into the machine) and what remains is removed by either air-drying or, more commonly, by one of the processes of machine ironing or pressing. The temperatures of all these processes are as a rule well controlled, being maintained by the use of saturated steam at constant pressure, and no damage to fabrics is likely on this score. There are some ironing machines, however, which are gas-heated and in these there is now a tendency towards the fitting of thermostatic controls to prevent overheating; two such instruments are the collar ironing machine and the electric hand-iron recently produced by the British Launderers' Research Association.

In general it may be said that modern processes of laundering are well controlled and chance effects, accidents, and other causes of fabric failure in the process of laundering being set aside for the purposes of this paper, those processes cause to the fabrics undergoing them the minimum of wear or other damage commensurate with proper cleansing. In a short space it is impossible to point out how that minimum is reached, but the British Launderers' Research Association has studied the necessary conditions extensively both from the mechanical and chemical aspects and is in constant touch with its many members throughout the country in order to assist them in maintaining it.

It remains now to point out the requirements in a fabric that go towards making it launderable, especially those concerning fabric structure. Primarily there is the need for fabrics to withstand the action of aqueous solutions of soap and alkali, of strengths ranging between 0·1 and 0·3%, and at temperatures varying between 15° and 100° C., without suffering damage or undue loss of strength. Most fabrics will withstand such treatment unharmed. Their structure is seldom at question in this matter; their resistance is mainly dependent upon the materials of which the fabric is made. Of these cotton, linen, wool, and silk are well known to be little affected by proper washing liquors although certain modifications of temperature and alkalinity are required to avoid damage to the latter two. The properties of the two artificial silks are also well known and these need cause the careful launderer no difficulty in avoiding damage. There are, however, materials used for fabric making which while having the appearance of one or other of the well-known five types of textile fibre, will definitely fail under the normal procedure of washing.

Jute is one example. In many cases jute is used to construct a fabric which simulates closely a linen or cotton material and it is only by properly carried out laboratory tests that the difference may be brought to light. In the average laundry there is neither time nor opportunity for conducting such tests, and as a consequence the article is classified as what it appears to be. Now jute is well known to be non-resistant to conditions of moisture and alkalinity, and the attempt to wash it by a process quite suitable for cotton or linen will almost inevitably damage it. It is not unfair, therefore, to say that fabrics constructed either wholly or partially of jute are not launderable by any present methods and as a corollary, only those fabrics which do not need washing should be constructed from it. This is, unfortunately, not always the case; several cases have recently come to light where this textile fibre was used for the making of cheap towels.

A second example of a similar kind is the use of very short staple fibre for the construction of yarns used in the weaving of fabrics. Such use probably originated during the war when extreme conditions made it necessary to search for new materials for fabric making, and as a result there were at that time many articles of clothing which could not be washed without disintegrating. A particular example was a shirt from which all the weft yarns disappeared in one washing, leaving a tangled mass of cotton warp yarns only. A more recent case in which a fabric has shown itself completely non-launderable by reason of disintegration of yarns in alkaline liquors is that of a mattress cover whose warp yarns were actually composed of twisted strips of paper. The fabric so produced was not unsuited to its purpose of covering the chains or ironwork of the bedstead and the fact that it was cheap is perhaps also in its favour. Such an article is, however, only to be cleansed by special methods—perhaps it might withstand the very mild treatment that silks and finery receive. It was, therefore, very surprising to find this mattress cover bearing a label: "Textilose, Washable, Mothproof, British Made". That label conveys to the purchaser the impression that a normal washing process, commonly understood as suitable for such an article as a mattress cover, is suitable for this particular one; that it is not so is shown by the photograph (Fig. 1) which also shows the real nature of the warp yarns and hence the cause of failure.

It might be argued that an article such as a mattress cover would require washing only at very long intervals, but such an argument could not be applied in the case of a tablecloth. Table-linen must be washed frequently and the nature of the soiling which it usually carries makes it necessary to employ methods of cleansing which are not provided for in the processes given to silks and finery. A tablecloth made from paper yarns would therefore have very little chance of surviving a single washing-process and yet there are many instances of such fabrics being sold and sent to the laundry.

Launderability is not, however, finally decided by the reactions of particular yarns or fabrics towards hot alkaline liquids since it is only in isolated cases that these are the cause of weakening or failure. A far more common occasion of failure is insufficient resistance on the part of the fabric to the mechanical rubbing already spoken of as necessary in washing. It is here that the structure of the fabric is so important. Unless the yarns of which it is composed and the manner in which it is woven are both designed to withstand reasonable wear under wet and possibly hot and alkaline conditions, the fabric cannot be considered as launderable.

The factors which eventually decide the degree of launderability of a fabric are such things as the staple length, the twist and the count of the yarns themselves and their relation to the design of the weave, particularly in respect of the number of ends and picks to the inch. Although from the point of view of wear alone the launderer would prefer to handle only those fabrics well balanced between warp and weft as regards twist, count, and sett, it is fully realised in the trade that the limitations that these conditions would impose upon the designer would be too exacting. Similarly the employment of only those weaves in which floats are of the shortest, welcome as they would be to the laundry industry, cannot be expected if irritating monotony of fabrics is to be avoided. There is no need for such restrictions as these, since the laundry industry can and does modify its processes mechanically to suit conditions. It is where the possibility of successful laundering becomes endangered that the launderer complains and he asks for immunity from blame in such cases as the following.

There is one form of wear, very common in occurrence, which is directly traceable to the mechanical action of the washing machine as a developing agent but which commences from a characteristic of the new fabric—thin straight lines of weakness form, usually along and roughly parallel to the selvedge of the fabric. These were considered in some detail in the previous paper (*loc. cit.*) and it is unnecessary to do more than to point out that they arise from an apparent tendency of most fabrics to fold themselves along certain definite lines. The rubbing action of the washing machine becomes localised and intensified along the lines of fold and hence in course of time what was initially merely a line of folding, becomes a line of wear. This is a very serious matter for all laundries and unfortunately there is very little control of the phenomenon possible to them. The suggested cause, put forward by the British Launderers' Research Association for the primary tendency of fabrics to fold naturally along given lines, is that an inherent weakness in line form is produced by the process of bleaching and finishing the woven fabric in ropes. At this Conference we are not concerned with that matter, but there is an analogous condition brought about we believe by a particular design and structure. If damasks are woven with long straight lines in the pattern, it is nearly always a fact that they break down in washing more rapidly than those in which the pattern consists of curves or shapes devoid of long straight lines. This is well known in the laundry industry and there are several cases on record where a laundryman, asked to advise an hotel or institution as to the type of damask most suitable for frequent washing, has passed on this information with very satisfactory results. The Greek "Key pattern" is a particular example of unsatisfactory design in this respect. As a rule the border of the cloth consists of a fairly wide band of Key design enclosed between narrow satin bands forming a straight line edging to the design. It is these long straight lines which fail first, and we suggest that their introduction in the pattern is a cause of initial weakness perhaps of a similar nature to the folding tendency already referred to as common among fabrics of plain or simple twill weaves.

There is little doubt that the straight lines are themselves the sole primary cause of the failure, even though the latter may be produced in part by the rubbing action of washing, however carefully that may be controlled. One example makes this very clear (Fig. 2). A particular damask tablecloth of very large size carried a bold design embodying in the centre a large oval band, somewhat like the conventional plan of a racecourse. In the course of time and many launderings, it was observed that the straight portions of the band, particularly although not entirely the long ones parallel to the length of the cloth, were failing, the main portions of the cloth being comparatively unaffected. Conversely it was particularly noticeable that where the band was on a curve, as it was near the ends of the oval, undue wear was not visible.

This difficulty with satin bands is of course a well-known one and it has been investigated by many and ascribed to more than one cause. We in the laundry industry are of the opinion that the real cause of the failure of these bands is to be found in a combination of localised wear due to the folding effect spoken of above and tension of the yarns of the band produced by the change from weft to warp face. The matter does, however, present some difficulty and is one which in our opinion is not as yet explained in an entirely satisfactory manner.

However much shrinkage or extra tension may be responsible for the failure of satin bands, there are many instances in which the sole cause of failure has been shrinkage of yarns. Unfortunately the shrinkage always becomes evident in the process of laundering. As a natural result that process is frequently held responsible by a disappointed owner of the particular fabric, but an impartial observer cannot fail to recognise the failure as another case of a non-launderable

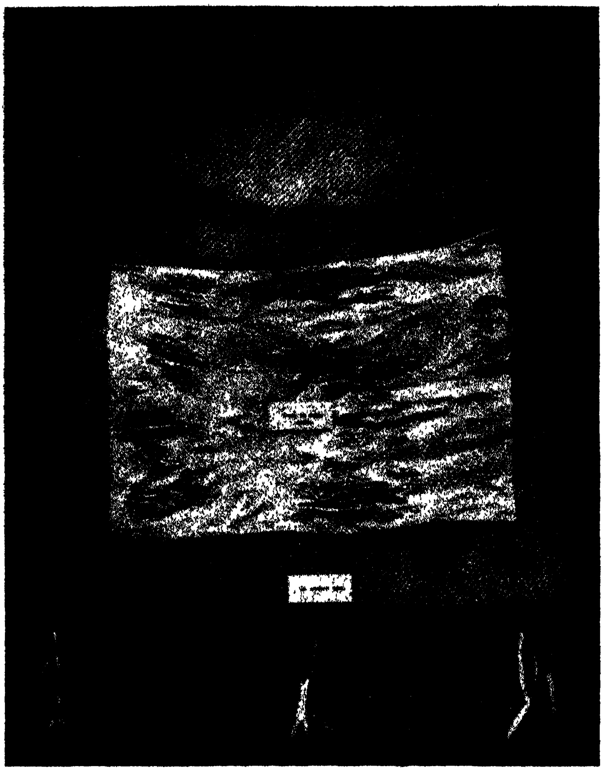

FIG. 1—Showing the original condition of a mattress cover made with warp yarns of twisted paper strip, and the condition after a single washing treatment normal for this class of article.

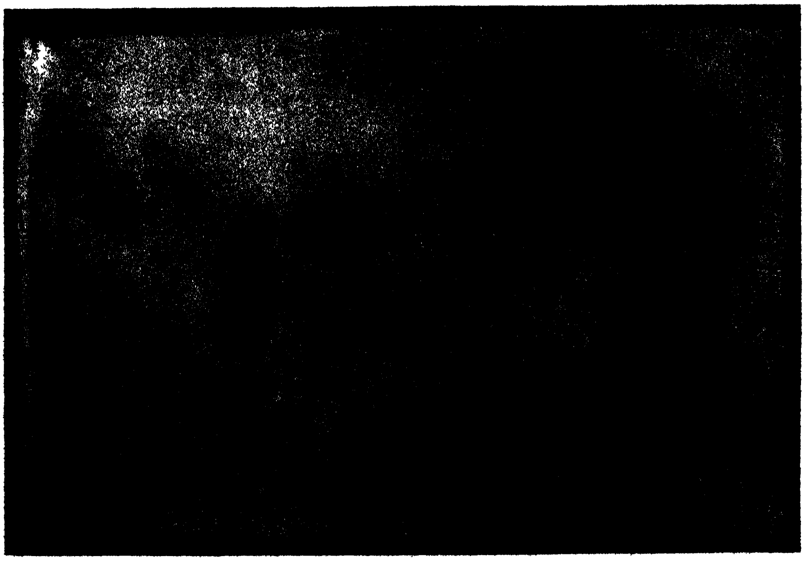

FIG. 2—The failure of straight satin bands on damask linen.

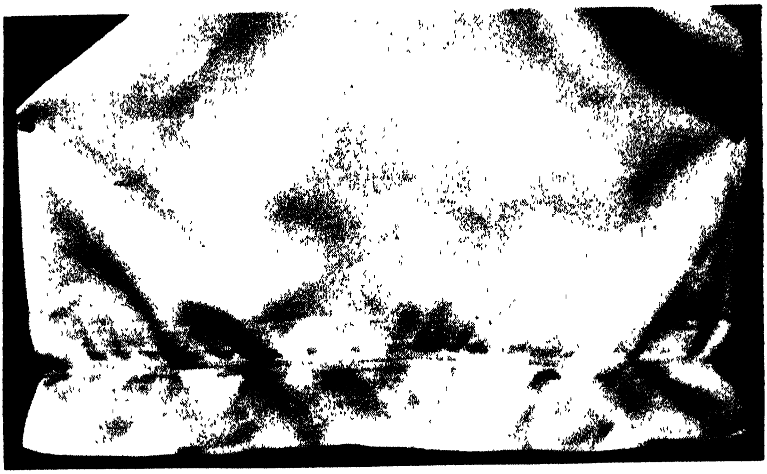

Fig. 3 Severe shrinkage of weft yarns in a towel, occurring in a band produced by the insertion of four picks in each shed

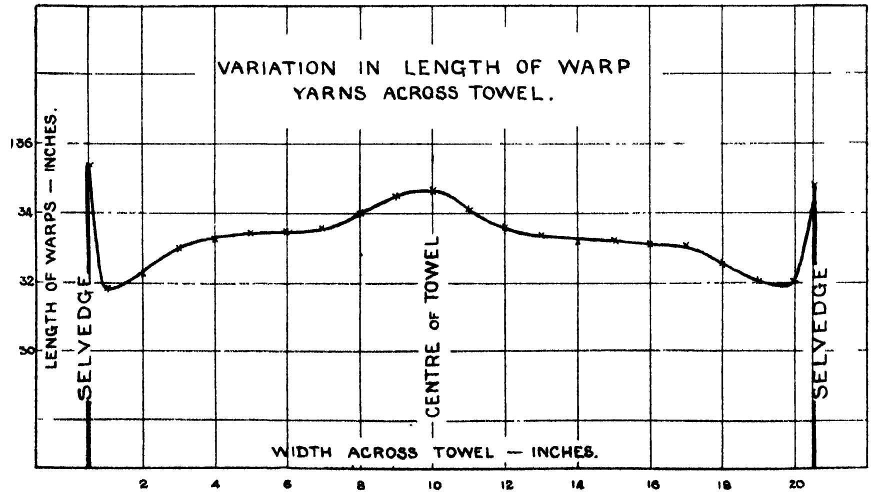

Fig. 4

fabric. Fig. 3 affords an example. The towel was of the normal huckaback variety, and its construction generally was unexceptionable except in one particular. A band across the fabric near the end had been produced by the insertion of a series of four picks of the normal weft yarn per shed but in the selvedges the shedding had been continued in the normal manner. In washing a large contraction of the weft yarns so woven had taken place, and it is suggested that such an effect might have been foreseen. The weft yarns are tightly held in the selvedges only, both on the loom and in subsequent washing. It does not seem unreasonable to expect them to be in tension different from the other normally-woven picks, in which case they must also shrink differently and cause the tight band and indentation of the selvedge to appear upon wetting. In the case of the particular towel shown in Fig. 3, the shrinkage was so serious that it could not be rectified; only by bursting the shrunken wefts could the towel be calendered square.

Uneven weft shrinkage does not necessarily result from an unsuitable design as in the case just quoted; it may be, of course, occasioned by the use of a slightly different weft yarn introduced at the change of cops. The Launderers' Research Association has recently received a complaint of this nature arising in the leg of pyjama trousers. At one point in the length of the leg, a sudden contraction in width was observable and this continued to the top of the garment in a perfectly even manner. A change of cop was the initial occasion of the shrinkage because it was found that although both weft yarns were union yarns, the fresh one contained between two and three times as much wool as that previously used. The explanation that a weft yarn of different shrinkage to the rest was introduced at that point does not alter the fact that the garment as a whole was not launderable.

An interesting case of uneven warp shrinkage is afforded by a second towel of the huckaback type. This was undyed and after washing by a suitable process was found to have developed two tight bands each parallel and adjacent to the selvedge. The same defect having occurred on both edges of the towel, the warp yarns were taken out at regular intervals of an inch across it and measured for length while under similar tension. These warp yarns (with the exception of those actually in the selvedges) were apparently of the same count and twist across the whole towel but their length varied as much as 10% (Fig. 4). The most remarkable fact about the variation is its regularity and it would be interesting to hear from a competent authority on the subject of fabric structure why it is that the warp yarns in the centre of the towel are longer than the majority of the others (except the selvedge yarns) and why the two tight bands have occurred in symmetrical positions. From the point of view of the laundry industry this towel is another non-launderable article since the presence of the two tight bands adjacent to the slack selvedges produced innumerable creases and folds which could not be ironed out without breaking the tight yarns.

Lack of balance between count and sett has been referred to already as a prolific cause of breakdown of fabrics in laundering and yet there is a large quantity of twill sheeting on the market which exhibits severe lack of balance between warp and weft yarns especially in the matter of count. These sheets are, of course, launderable in that they will withstand washing a few times, but seeing the nature of their use and that bed-sheets must be washed often it would seem that more account should be taken of the necessary characteristic of a weave to withstand washing satisfactorily.

A similar lack of provision for the effects of washing and in this case even for the needs of wear is found in the case of Terry towelling. This has been dealt with fully in the paper mentioned above but should be referred to again. It is probably accepted from the point of view of wear, and of launderability as well, that the four- to six-pick Terry fabrics are more satisfactory than the three-pick whose pile loops depend almost entirely for their hold upon the tightness of the ground-weave, there being no locking device to hold them in position. Yet the number of three-pick Terry towels on the market completely overshadows those of more satisfactory design; only some 3% of the bath towels reaching a London laundry in one week were other than the three-pick variety.

Other points of fabric structure which seriously affect launderability might be referred to, among them the slippage of yarns such as occurs in slub-repp fabrics, but the purpose of this paper is to use examples merely as pointers to general principles.

The launderers' processes cannot claim to be perfect but they have improved so very greatly during the last decade and show so great a tendency to improve still further that the time is approaching when the best conservator of fabrics in this country will be the expert industrial laundryman. He is rapidly learning that the fabrics he handles require and will withstand certain definite treatments in their cleansing and he is also appreciating that departure from those definite treatments will be followed by disaster for which he is responsible. He is, therefore, standardising his methods in every way possible and will welcome co-operation from designers and makers of fabrics, but at the same time he is asking questions as to why such failures as this paper has dealt with need occur, and whether he can assist in pointing out that certain structures should be avoided in order that the launderability of fabrics may be counted upon.

LACE FABRICS

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Lace fabrics are entirely decorative, in which direction they render a service unattainable by any other textile material. The selection of a lace for a particular purpose requires discrimination, but the correct combination is remarkable. Lace nets are an indispensible part of some lace fabrics, and in themselves are in a smaller measure, decorative. Even plain nets possess a regularity of mesh which commands attention; the only disturbing factor being the irregularity of the yarn employed. One quality of plain net is of particular service to mankind, in protection from the mosquito and other winged insects, by draping around the bedstead or cot.

Efforts to improve the appearance of garments, particularly underwear, have undoubtedly increased sales. It is worthy of note, that there is an increasing inclination for an artistic trimming, and for such trimming to be of lace. Laces most suitable for this purpose have received the special attention of manufacturers, who can create a lace which is difficult, if not impossible, to distinguish from the highly prized hand-made lace. Lace is the oldest, and by far the most delicate decorative fabric.

The word "lace" is said to be derived from the Latin word "lacina", signifying the hem or fringe of a garment. Other authorities contend that it is of Anglo Saxon origin, because the term "lacez" was rendered "laces" in a statute of Edward III. It implied braids such as were used for uniting different parts of the dress.

Lace is defined in the dictionary as being "an ornamental fabric of fine threads curiously woven", a definition which might be interpreted as threads of one or more various materials, interwoven, drawn, plaited, looped or twisted, to form a patterned texture. It was originally produced either by drawing the threads of fine cloth in various directions by the needle, and securing them to form meshes and figures composed of open-work and close-work, to which might be added embroidery, or by cutting the cloth ground and securing the edges by the crochet hook or needle, sometimes inserting braids of narrow breadths, woven or plaited, to be used in forming figures by being joined together at points required by the pattern.

The unlimited possibilities available for designing by this hand manipulation of the needle, provided unusual opportunities to express individuality. The result was that certain types gradually became peculiar to the districts in which they originated. The origin of lace making is unknown, but Italy is credited with being the cradle of the point lace industry, which appears to have reached its climax in the production of Venetian point.

Venetian point is chiefly distinguished by the conventional treatment of the flowers and ornaments, and a general raised appearance of the work, from which it obtains the name of "raised point" or "gros point". The outlining thread or cordonnet is stitched to the edge of the pattern and worked in flatly, and the needle stitch employed to connect the pattern was such as to give it the name of "punto in aria" or stitches in the air. The Venetian product is said to have surpassed in fineness both "Alençon" and "Brussels". Modern Venetian laces made with the bobbin are called "Guipure de Venice" or "Point Plat de Venice".

In French needle point, the making of "Point de France" appears to have merged at a very early period into "Point d'Alençon" and "Point d'Argentan". The making of "Point d'Alençon" required as many as twelve processes in its manufacture, some of which were again subdivided, making as many as twenty-two. The pricked parchment was stitched to a piece of linen folded double, the outline of the pattern formed by two flat threads and fixed by minute stitches.

The work then passed to the "réseleuse" to make the ground which is of two kinds—bride and réseau. In addition to the hexagon bride ground and the ground meshes, there was another variety of grounding used in Alençon lace.

This ground consists of buttonhole stitched skeleton hexagons, within each of which was worked s small solid hexagon, connected with the surrounding figure by means of six little ties or brides. Lace with this particular ground has been called "Argentella". The buttonhole stitch (point noué) was used in making the flowers; then followed the modes (fillings), and other operations. When completed, the threads which unite the lace, parchment and linen together, were cut with a razor passed between the folds of the linen, and any little defects repaired. Then remained the most difficult task of imperceptibly uniting all the segments together, an operation in which horsehair was introduced along the edge, to give firmness and consistency to the cordonnet. The stitch by which these sections are worked is termed "assemblage", and differs from the "point de raccroc" or fine joining, where the segments are united by a fresh row of stitches. When finished, a steel instrument called a picot is passed into each flower to smoothen the surface

Point d'Alençon is of a solidity which defies time and washing, and has been justly called the Queen of Lace. The old custom of assigning a special branch of the work to each lace maker was eventually discarded, and the lace executed through all its stages by the same worker, obviously at the expense of quality. Point d'Alençon may be considered as a lace with a fine réseau, the mesh of which is more square than hexagonal in form, worked by looped stitches across horizontal lines of threads, with the flower or ornament worked in fine point stitches closely resembling the gimp or ornament in "Point de Venice" réseau, and outlined by a cordonnet of the finest buttonhole stitches worked over a horsehair or threads. (See illustrations of Point Réseau and Lille).

Point d'Argentan is a lace with similar work to Point d'Alençon as regards flower, ornament and cordonnet, but with a hexagon bride ground; each side of the hexagon being of the finest buttonhole stitchings. It consists of a six-sided buttonhole bride fringed with a little row of three or four picots or pearls round each side.

Some laces, points, and guipures are not worked upon a ground; the flowers are connected by irregular threads overcast (buttonhole stitch), and sometimes worked over with pearl loops (picot). These uniting threads are called "pearl ties" by the English, "legs" by the Italians, and "brides" by the French. The open-work introduced into the pattern is known as fillings (modes and jours).

Brussels lace was curiously made. The sprig, leaf or flower was made by one person, handed to another to be grounded, and then to a third worker who hearts all the flowers with openwork. Extremely fine thread was used, which, in order to avoid contact with the dry air, was spun in damp cellars where a ray of light was admitted and focussed on to the thread. The real Brussels ground owes a great deal of its value to the fineness of the thread, and was formed by four threads composing the upright pillar, and two threads twisted to form each of four sides of the mesh. The flower or ornamental pattern was made separately, and then either worked in or sewn on, giving laces the name "appliqué". (See illustrations of Brussels and Mechlin).

Mechlin differed from Brussels in that it was wrought in one operation, and is distinguished by the cordonnet or flat thread which outlines the pattern, giving the lace the character of embroidery. The hexagonal mesh of the réseau or ground is made of two threads twisted twice on four sides, and four threads plaited three times on the two other sides. The mesh is consequently smaller than that of Brussels.

The various kinds of needlework lace had reached a high degree of perfection in most European countries, when the art of pillow lace making was invented by Barbara Uttmann of St. Annaberg on the borders of Saxony, in the year 1561.

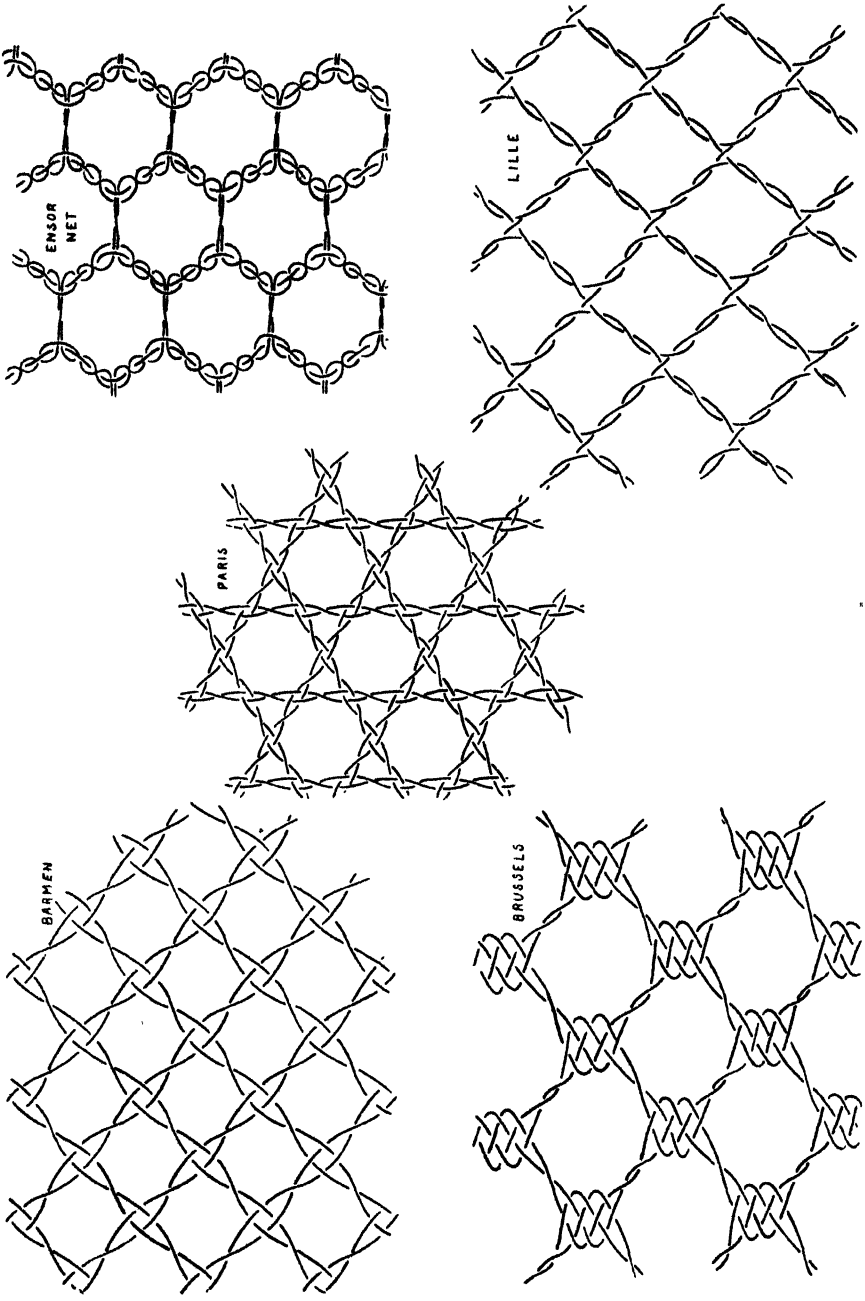
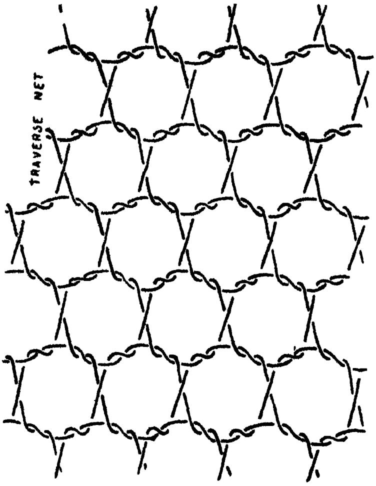
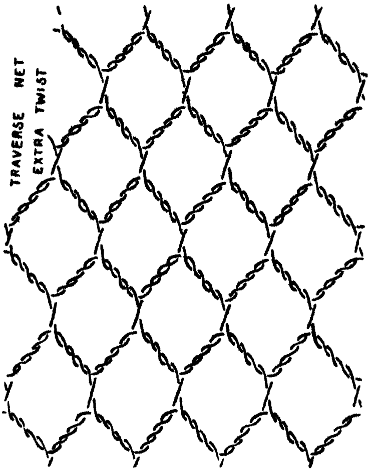
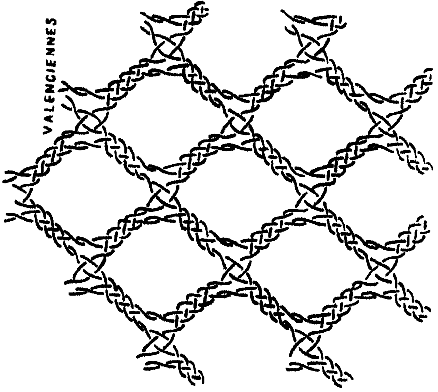
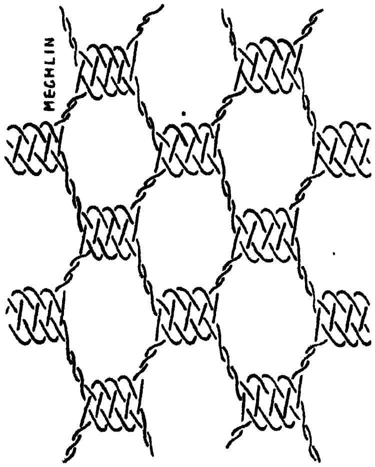


PLATE I


TRAVERSE NET


TRAVERSE NET
EXTRA TWIST


VALENCIENNES


MECHLIN

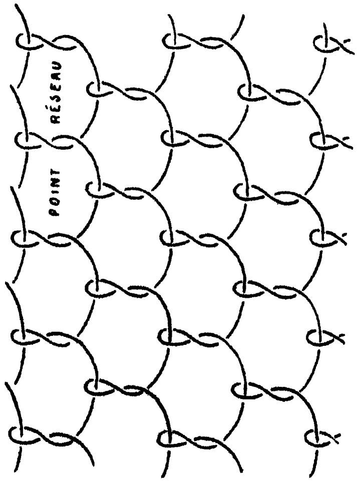

POINT RÉSEAU

PLATE II

Pillow lace making is a mode of netting, twisting or plaiting threads, drawn from spools or bobbins, into lace, by passing them round pins upon a cushion. The making of ornamented lace by this method required a number of threads supplied from individual bobbins, a cushion, a design traced and pricked upon paper, and two sorts of pins. If a mesh is to be triangular three pins would be necessary; if quadrangular four pins, and one placed in the centre to produce the opening required. Twisting is accomplished by passing the threads round each other a certain number of times according to the kind of mesh desired, then round the supporting pins which remain to support the mesh for a considerable period. To complete the mesh, a "coronne", i.e. a crown, cross or knot is necessary to close up, tie or bind the work. In the mesh resembling weaving, the threads are laid under and over without twist, and the clothwork is finished by a groundwork of small meshes. Pillow lace is described in the Encyclopædia Française as being a combination of gauze, weaving, and embroidery. Of embroidery because there are many points and thick threads introduced; of weaving because there are parts where there are proper warp and weft; and of gauze because patterns are executed upon it, and the threads which might be considered as being warp and weft, are often withdrawn from each by crossings. Barbara Uttmann must have possessed an analytical mind, great genius, strong memory and unwearied patience, to have devised and executed such a plan of fabric structure, capable of infinite variety in design and perfect beauty in its execution.

All lace is terminated by two edges—pearl or crown, and the lacer. The name "dentelle" appears to have originated from the picot or pearl on the edge arranged like small teeth.

Differences in points, designs and work distinguished the different parts and kinds of lace. The distinction however is difficult to define, because some laces described as "point" are partly made on the pillow. "Point de Valenciennes" or "Point de Malines" are both pure bobbin laces, so that "point" is simply a term employed. (See illustrations of Valenciennes and Paris).

Valenciennes lace was made entirely on the pillow, the lace ground being made in various ways; by twisting the bobbins two-and-a-half times, three, three-and-a-half or four times. Its mesh was therefore generally square or diamond shaped, all its sides being closely plaited, and called double-ground. The ornament is not picked out with a cordonnet as in Mechlin, neither is it raised as in Venetian point; the design lies flat, but is defined by a fine line of picks.

From the foregoing description of a few of the many laces made by hand, it will be realised that the rate of production set a correspondingly high price on the article, certainly beyond the means of all but the wealthy. The possession of lace was highly desired by the mass of the people, creating a demand which presented a very promising field to those who were already producing fabrics of a decorative nature on machines.

Looped articles of perfect regularity were successfully produced on the stocking frame, and so highly appreciated as to lay the foundation for the present machine-wrought lace industry. The regularity of the net, however, was a different proposition. Net was certainly produced, but without a single characteristic of real lace, though called Valenciennes. Open-work in real lace was imitated by the removal of certain loops from the needles, and the open-work surrounded with needle work; an operation called lace-running. Square net was obtained by a tuck presser and points on the principle of the Derby rib frame, and by employing independently controlled tuck pressers; "flowered net" was produced by leaving certain parts plain.

The mechanical production of a perfectly regular mesh, was engaging the attention of skilled craftsmen who realised the difficult proposition to be overcome. The result of their efforts was the Point net machine, which successfully made a perfectly six-sided mesh, and was called "point net".

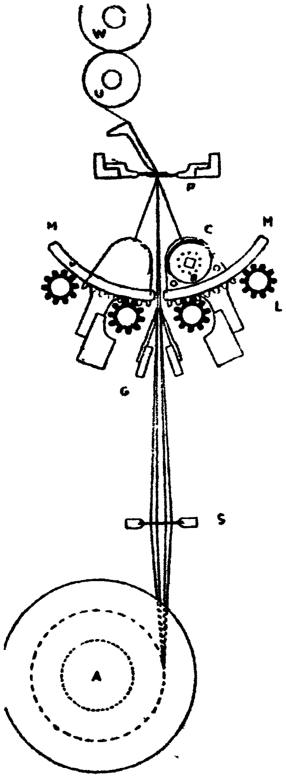


Fig. 1—Rolling Locker

W	Work roller	M	Comb
U	Porcupine roller	L	Fluted roller
F	Facing bar	G	Guides
P	Points	Y	Sley
C	Carriage	A	Warp beam
B	Bobbin		

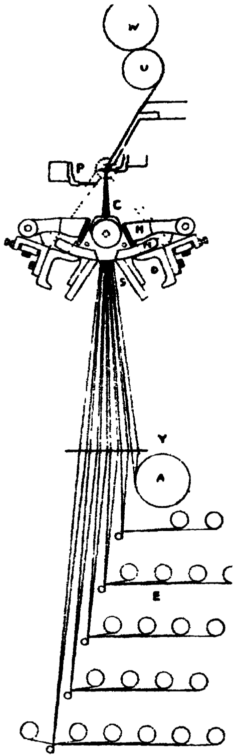


Fig. 2—Levers Machine

W	Work roller	M	Comb
U	Porcupine roller	D	Landing bar
F	Facing bar	S	Steel bars
P	Points	Y	Sley
H	Catch bar	A	Main beam
C	Carriage	E	Independent beams
B	Bobbin		

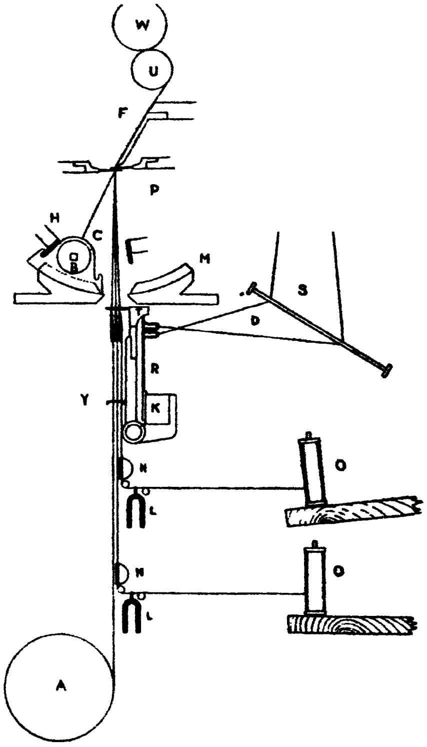


Fig. 3—Curtain Machine

W	Work roller	M	Comb	T	Trick bar
U	Porcupine roller	B	Bobbin	N	Nipping bar
F	Facing bar	R	Intercepter	O	Spools
P	Points	D	Jacquard strings	Y	Thread Sley
H	Catch bar	G	Guides	S	String Sley
C	Carriage	K	Rocking bar	L	Lingoe
				A	Warp beam

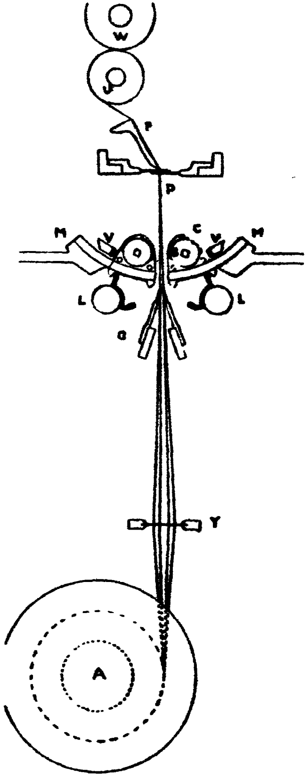


Fig. 4—Double Locker

W	Work Roller	M	Comb
U	Porcupine roller	L	Locker bar
F	Facing bar	G	Guides
P	Points	V	Driving bar
C	Carriage	Y	Sley
B	Bobbin	A	Warp beam

Warp laces were a distinct development in lace manufacture. In this machine, a thread was given to every needle, by which its powers of varied production far exceeded those of the old weaving loom, the stocking frame, the point net machine or any other. The substitution of a warp thread to every needle, instead of confining the whole set of needles to successive loopings upon one thread, introduced great facilities for varying the meshes. The machine was therefore adapted for the manufacture of both plain and figured lace, and included the lightest gossamer silk net lace, silk blondes and edgings, cotton tattings and pearls, antimacassars and d'oyleys of effective designs, thick threaded, pearled and finished in the machine.

Point net and warp net were being made in large quantities, but a fast meshed lace had not yet been mechanically achieved. The difficulty lay in providing for the threads twisting round each other, and then travelling in three separate sets of directions. The twist had been obtained, but not the traverse, which was essential to the soundness of the twisted net.

Traverse net exactly like that from the pillow, was an entirely new departure in mechanical ingenuity. John Heathcote conceived the idea of an independent control of a series of threads from bobbins and carriages. Dr. Ure says "to this machine must be traced the origin of the curious invention of the bobbin and carriage; to it must be referred the method of using two divisions of threads—warp and bobbin; and to it alone must be attributed the beautiful idea of passing, or as it is generally termed, twisting two divisions of threads with order and regularity and without entanglement, round each other". This first bobbin net machine did for the making of lace in relation to the pillow, what the jenny did for the spinning of yarns in relation to the old long wheel. Lace of ordinary fineness required forty threads in each inch of width, presenting a real difficulty in times when the art of making disc bobbins and carriages was in its infancy. The limitation in mechanical skill to making bobbins and carriages as thin as was requisite for the quality of lace, compelled Heathcote to design a double tier machine. Modern engineering has transformed this "old Loughborough" into a high speed "rolling locker machine". (Fig. 1.)

"Bobbin net", "mosquito net" and "cable net" are the fine, medium and coarse classes of traverse net made on this rolling locker machine. Each class of net is distinguished by its quality and count of yarn, but characterised by the fact that the structure is identical, *i.e.*, they are each twelve motion traverse net. Apart from structural modifications due to weight, the machines only differ in width and point. The width in inches refers to the actual width of net which can be made on the machine; the point refers to the gauge, sett or number of combs in the space of one inch in one bar—360 inch 6 point, yarns 16/2 and 20/2, cable net; 274 inch 8 point, yarns 40/2 and 32/1, mosquito net; 220 inch 12 point, yarns 120/2 and 60/1, bobbin net. The latter would have 5,280 bobbin threads, minus a number determined by the position of the turnagain; also minus a similar number of warp threads with an allowance for selvedges. These traverse nets are a combination of the traversing of the bobbins, and a lateral movement of six motions each of the two warp guide-bars. (See illustrations of Traverse net and Traverse net extra twist).

A "piece" of bobbin net, is the amount of net which can be made from a full wound set of bobbins, and its length depends upon the number of yards of yarn a bobbin can hold. Such a piece is designated by its width in inches, point, and holes per inch in a vertical direction, such as 274/10/16, and its length as so many racks. A rack is a standard number of motions upon which a lace maker is paid, which, in the case of bobbin net consists of 2,880 motions. Dividing this figure by the number of motions required to make one hole, gives 240 holes in one rack. Given the racks of the piece referred to as 108, the length of the piece would be 45 yards. The width, point and material, are factors upon which the rate of pay depends. The rate is then increased according to the quality and kind of net made on this type of machine. The introduction of symetrically arranged spots on the plain traverse ground is very effective, but accounts for many hundreds of lost motions in a rack. There is a tendency in all laces for the ground to be distorted by the element introduced. This is particularly the case with spotted net, because the tension of the bobbin thread from which the spot is made must be maintained both before and after the spot. Attractive designs are also made on the traverse ground by independent beams and extra guide-bars. In addition to vertical stripes of varying width and density, the stripes can be made to traverse, and form diagonals and symmetrical figures.

In order to supply the demand for bobbin nets of narrow breadths with perfect selvedges, locker bars and pusher bars are substituted for the fluted rollers. These blades are fitted in sections, either to form continuous blades, or divided, to enable the bobbin threads to be turned at any predetermined interval in the width of the machine. One type of machine employed for this purpose is known as the "double locker", and, owing to the system employed in controlling the carriages, is claimed to work a weaker yarn, but in comparison to the rolling locker, the production is low. (Fig 4.)

The success of Heathcote's patent led to attempts by others to produce the same mesh in a different way. The first successful attempt was the "traverse warp machine", which very ingeniously reversed the order of the threads. The machine was judged an infringement, but was, however, a great improvement, in that it was capable of making narrow breadths called quillings, each breadth having its own selvedges, and being provided with drawthreads, which when withdrawn, left a perfect breadth. Developments in the traverse warp machine, by the addition of flat metal bars controlled from an organ barrel, enabled many warp threads to be used, by which a copy of "French Blonde" was so perfectly made, as to be sold as real lace, for a long period, without detection.

Improved mechanical skill enabled John Levers to obtain bobbins and carriages half the thickness of Heathcote's, and so construct a single tier machine, such as was the original intention of Heathcote. By controlling alternate carriages at alternate periods, traverse net was successfully produced, and from accounts of modifications which developed to an extraordinary degree, the machine was adaptable to the most complicated designs in the manufacture of lace. Even Brussels lace was successfully made.

Traverse laces were then subjected to competition by straight-down Levers goods, in which the jacquard was adapted. Improved mechanism enabled the machine to be converted to rotary action almost the same as is at present employed. Fender net was made, which later developed into "Mechlin". The improved application of the jacquard increased the possibilities of the Levers machine to a degree impossible with the organ barrel, and to a still greater degree when steel bars were substituted for flat metal bars. An important feature of the steel bars controlling the warp threads, is extensive increase in the capabilities of the machine by the addition of another set of bars called bottom bars, especially in connection with fine warp threads, and for making variations in the ground and the fining, as in Grecian, French, fillings, pheasants' eyes, etc. The purpose of the bottom bars is to enable nearly the whole of the top bars to be used for gimping and thick threading. The structure of a lace demands an unequal supply of yarn from the warp; certain threads are therefore wound on a series of small independent beams, in which the tension of each is of the utmost importance Both positive and negative methods of tensioning are employed, the latter method being most common. The set-out of the threads on the independent beams, together with the count, twist and material is determined before drafting. (Fig 2.)

The act of moving a thread either to the right (up), or to the left (down), is called a throw, and does not mean any specified distance. A "pillar" is a term used to denote the thread or threads that form one-half or any less portion of a mesh of net, without regard to the size of such mesh, under which circumstances it is called a net pillar. It is also used to denote any portion of a fabric which gives prominent support to any part of any figure in the design. (See illustration of Ensor).

The quality of a Levers lace is judged by the length of a rack, which always consists of 1,920 motions, but the length of a rack may be anything from six inches to forty inches. In finer qualities it is sometimes impossible for anyone other than the maker to accurately determine the length of a rack. The motions, width in quarters, gauge, number of bars and material, are all factors upon which the price per rack is paid to the twisthand.

Go-through machine lace is made on the same principle as Levers lace. The pieces are of greater length, owing to the increased size of the bobbins and carriages. The combs are of sufficient length to dispense with the landing bar; the machine is of more rigid structure, and, owing mainly to an improvement in the movement of the catch-bar, can be driven at a very much higher speed.

Lace curtains originally consisted of embroidered or tamboured plain net, or were manufactured as complete articles on Levers and Pusher machines. The perfection of the present curtain machine is, to a great extent, due to the skill of a draughtsman, in combining the parts or processes of various machines. The material consists of main warp threads and independent spool threads, each controlled by guide bars in the well of the machine, and bobbin threads. Intercepter wires, immediately below the carriages, intercept each row of warp and spool threads, and move them one gait up and one gait down, irrespective of the movement given to the guide bars by cams. Such a movement would only produce pillars consisting of warp and spool threads round which the bobbin threads are twisted. The intercepter wires are individually connected to a Manchester top jacquard, and can therefore be entirely withdrawn, when the movements of the guide bars would produce solid cloth. The combination of this pillaring and clothwork is the product known as curtain lace, and the principle involved is called a negative one. The lace is therefore characterised by the fact that the machine is set to make a cloth fabric, the pattern being made by preventing the formation of the cloth fabric by intercepting the movements of the threads contained in the guide bars by the jacks. In ordinary work, the jacks enter before each passage of the carriages from the back to the front, and back again. In "double action" and Swiss work, the jacks are entered before the carriages enter from the back, and again before they go from front to back. In extra bar work and combination, the jacks are arranged to enter the threads at various distances, so as to intercept all the threads or only part of them, i.e. the threads in all the guide bars or only some of the bars, in which case two jacquards must be employed. Numerous patterns can be made with two bars and one jacquard owing to the fact that the spool threads may be shogged two, three or four gaits, according to the density and design of the fabric. Four gait double tie cross ground requires two extra half bars. Two and four gait double action requires two jacquards. Two gait Swiss four gait spool thread, requires three guide bars and two jacquards. Combination necessitates one jacquard being driven at twice the rate of the other. Four gait double tie barground "Madras" requires two warp beams. It is important to note that in "combination" the jacks of one jacquard are set to intercept the spool threads only, leaving the warp threads to draw the mesh and produce openwork. Each pattern of curtain lace must have a predetermined movement of individual guide bars. This movement is provided by a form of Dawson wheel, equally divided into eight, ten or twelve divisions, according to the ratio of gearing employed. A remarkable difference in effect is obtained by substituting two half bars for one full bar, and reversing the order of two similarly cut wheels or cams, as in straight bar Swiss. (Fig. 3.)

Barmen lace is made on a braiding machine, in which the patterns are made by suppressing the crosses. The lace is made in tubular form on the principle of the maypole, and is an exact mechanical reproduction of pillow lace. Vertically placed bobbins are made to traverse along zig-zag tracks to reverse with each other at any of the crossings, or to pass each other in their circuit. A lacing thread is inserted at the limit of the track, so that the fabric is tubular. On removing the lace from the roller, the lacing thread is withdrawn, giving a breadth of lace with perfect selvedges. This kind of lace is made in a great variety of qualities, and is sometimes erroneously called "torchon lace". (See illustration of Barmen).

Embroidered lace requires a groundwork of either plain net or Brussels net. The net is dressed to give the mesh the desired shape, and the piece is then secured to a rectangular frame several feet in length and depth. The frame is supported and balanced to be moved in any direction in its own plane by a pantograph, between a row of needles extending the whole width of one side of the piece, and a row of corresponding shuttles on the other side. The pattern to be embroidered on the net is enlarged, usually six times, and is secured to a vertical board at the end of the frame. The outline of the enlarged pattern is marked with large dots, on which the pointer of the pantograph is to be placed by the operator at each release of the frame, i.e. at the completion of the stitch made by the needle and shuttle. By this means, both complicated and heavy designs are incorporated with the traverse groundwork, and repeated across the whole width of the frame. Another form of embroidery consists of outlining the pattern in the lace by a thick thread, which is called lace running. This is frequently necessary in a "pusher lace", which is distinguished by the flatness of the design. A Michilet machine of the Cornelly type successfully performs this operation, and accounts for the thick thread running in every conceivable direction.

All pieces from the machine are taken to the mending room, to be carefully examined and to have dropped threads replaced, and then transferred to lace dressers to be scoured, bleached or dyed, and dressed to correct width and length on spiked frames, on which they are dried. In order to present the lace in saleable form, the final operations of withdrawing lacing threads, clipping, scalloping and mounting are necessary.

The art of meshing is a science which alone enabled the important advances in the manufacture of lace to be made. It comprised the analysis of the fine-works, open-works, thick threads, points and pearls which go to make up the texture of each class of lace; an effort requiring the combination of an artist and a draughtsman. The design must be within the capabilities of the machine, open-works and finings must balance, the edgings and general design must have harmony, and be so arranged as to be exactly copied upon the draft. The work of the draughtsman is to transfer the design in various coloured inks on to specially ruled drafting paper, whose columns correspond to the motions and to the gauge of the machine. A figure sheet is built up from the completed draft, each line translated into figures, threads and motions numbered in sequence, and numerical representation of the movements of different threads shown on the draft. The figure sheet is now the working basis from which the jacquard cards are punched, and laced together to form a continuous band: one set for the front motion, and the other set for the back.

Lace making is an intricate industry; each of its various branches, *i.e.* nets, lace curtains, fancy laces and embroidery, is a distinct industry. It is a well known fact that at the present time, nearly every known mesh, certainly every useful one, has been mechanically produced, and into most of them elaborate and tasteful designs have been introduced, so that some articles made on the machine are often distinguished with difficulty from those made by hand.

PREPARATION OF HARD-TWISTED YARNS FOR CRÊPES

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Crêpe fabrics, manufactured from almost all types of textile materials, have enjoyed and are still enjoying a large measure of popularity They are made in a variety of textile materials, chiefly silk, spun silk, rayon, spun rayon, worsted, and cotton, or a combination of any of these materials.

There are two distinct types of crêpe fabrics, (*a*) those which are constructed from highly-twisted yarns in both warp and weft, as exemplified in silk, rayon, and cotton voiles and georgettes and (*b*) those which are constructed from soft-spun threads in one direction and highly-twisted threads in the other direction, as exemplified in crêpe-de-chine, crêpe suedes, ray-de-chines, elephant skin crêpes, etc.

The popularity of real silk crêpes, as crêpe-de-chine, georgettes, and voiles has always been very high, only the relatively high cost of the raw material and of the finished cloth has limited the demand for these fabrics. The very nature and physical properties of real silk yarn produce a fabric which possesses excellent draping qualities, of a soft handle and resistance to creasing when in use. It was only to be expected that a fabric with such rich qualities would be imitated in other cheaper textile raw materials such as rayon, worsted, and cotton, or any of these in combination with real silk, thus bringing the price of the finished fabric within the reach of a much larger community.

Silk, Rayon, and Cotton Crêpe Yarn

The production of high crêpe twists in silk and rayon calls for a great amount of skill and ingenuity on the part of the throwster who is responsible for the twisting operation, and the production of an evenly-twisted thread. During the past few years, there has been a tremendous growth in the use of silk and rayon yarn twisted with crêpe turns. Crêpe twists are produced in single, two, and three-thread real silk yarns, but the largest increase and the greatest progress has been made in the production of crêpe twists in viscose and cuprammonium rayon yarns. Acetate rayons on account of their soft nature have not yet been very successful when given high crêpe twists. The turns given to silk and rayon yarns for crêping purposes vary somewhat, but the following are practical examples.

Real silk crêpe twists, two-thread, 13/15 denier with 65/70 turns, 70/75 turns; three-thread, 13/15 denier, 60/65 turns, 65/70 turns.

Rayon crêpe twists, 40 denier cuprammonium rayon, 60/65 turns; 75 denier viscose, 60/65 turns, 100 denier viscose, 55/60 turns.

Rayon throwsters usually claim a tolerance of about 5% in turns either above or below the average. A wide variation is liable to produce defects in the finished fabric; the most common of which is river marking, or uneven crêping. It is generally well known that in order to produce the correct crêping effect in the cloth, crêpe threads are arranged in warp or weft, or both ways in equal proportions of right twist and left twist respectively. In order that the operative may readily distinguish the two kinds of twist during preparatory processing and weaving, it is necessary that the two kinds of yarn be tinted in two contrasting colours. The tinting process is usually carried out while the yarn is in the hank state previous to winding on to flanged bobbins.

Silk Crêpe—Raw silk in the gum state is much too harsh to be twisted with high turns as the delicate filaments would break down under the strain. Silk is first soaked in aqueous emulsions of soap and oil, with added softening and hygroscopic agents. This soaking operation renders the silk soft and pliable and reduces static electricity; soaked silk absorbs water and is therefore in a better and more pliable condition for running in the twisting, winding, warping, and weaving processes. Fugitive dyes are added to distinguish between yarn to be given right and left twists respectively.

Rayon Crêpe—The low elastic limit, and the peculiar physical properties of rayon do not lend themselves to the production of very high twists and the high speed of twisting usually associated with twisting real silk yarns. In order to render the yarns more pliable and enable high twists to be inserted without breakage or cracking of the filaments, it is necessary to treat the material with some softening substance and at the same time an adhesive to form a flexible film on the yarn to bind the filaments together. This treatment assists the twist to set better and prevent it from creeping.

For the purpose of imparting adhesiveness, various starches, gums, or gelatines are employed, while soluble oils and waxes are used as lubricants and softeners. The following preparation is recommended as a suitable treatment for a 100-denier rayon to be twisted with 50/55 turns.

> 3 lb. of gelatin is mixed with approximately 5 gallons of water, and heated to 65° F. 14 lb. of soaking oil is mixed with 10 gallons of water, agitated, and then added to the gelatin. The whole mixture is heated to 130° F.

For the purpose of identifying right and left-hand twists fugitive dyes are added; about 2 oz. per 100 gallons. A solution of about 50 gallons will be sufficient to soak 100 lb. of yarn The hanks of rayon are placed in loosely woven bags or nets and immersed in the soaking solution, and left for about 20 minutes. The bags are then taken out and hydro-extracted, after which the hanks are taken and shaked out loose, hung straight on poles with a little space between each so they dry straight. They may be then dried at about 150° F., leaving 10 to 11% of moisture present.

Cotton and Worsted Crêpes—The number of turns given to cotton and worsted crêpe yarns varies from 6 to 10 × $\sqrt{\text{counts}}$. A large variety of counts are now used and the turns are varied to secure the crêping effect desired. In cotton, the standard sizes are 2/40's to 2/140's in both right and left twists, and always "Twist on Twist" and "Weft on Weft" or, the doubling twist in the same direction as the singles twist. They are made in singles counts from 1/16's to 1/80's: in worsted 1/30's to 1/50's and in 2/60's to 2/120's.

Movement of Twist in Crêpe Yarns

Unless the twist is properly set in the yarn, there is always a tendency for the twist to move from one part of a thread to another, especially if there be any unevenness in the thread itself. The most twist always runs to the finer parts of the thread. This creeping of the twist in crêpe yarns is a source of trouble and the cause of many faults in the finished fabric, as well as difficulties in the preparation and weaving. A thread may appear practically lifeless in one portion, while another portion may be full of snarl and spring. To avoid creeping of twist, the thread should not be run over any stationary surface under tension, if at all possible, as this is often the cause of disturbing twist. This can easily be demonstrated with any crêpe thread by running the thread between the fingers and applying light pressure. Then allow the thread to hang slack. It will appear lifeless, while the neighbouring portion not so treated will have excessive twist and be very lively and difficult to straighten out.

Setting of Twist

Crêpe yarn after twisting cannot be prepared for the loom in the condition it leaves the spinning or twisting machine. It would be too lively and develop large numbers of snarls immediately the tension on the thread was released. In the case of silk and rayon as well as with cotton and worsted crêpe twist, setting is carried out by a special steaming process. Quite good results are achieved by subjecting the yarn to dry steam in a vacuum. With silk and rayon care must be taken to avoid over steaming, and water from condensation falling on the yarn. Another method is to stand the yarn over a basin of water through which water vapour bubbles. The moisture sets the twist and experience has generally shown that several short periods of steaming alternated with periods of conditioning give better results than one long period of steaming. In all cases crêpe yarn after final twisting and setting should be allowed to condition at room temperature for a few days before processing.

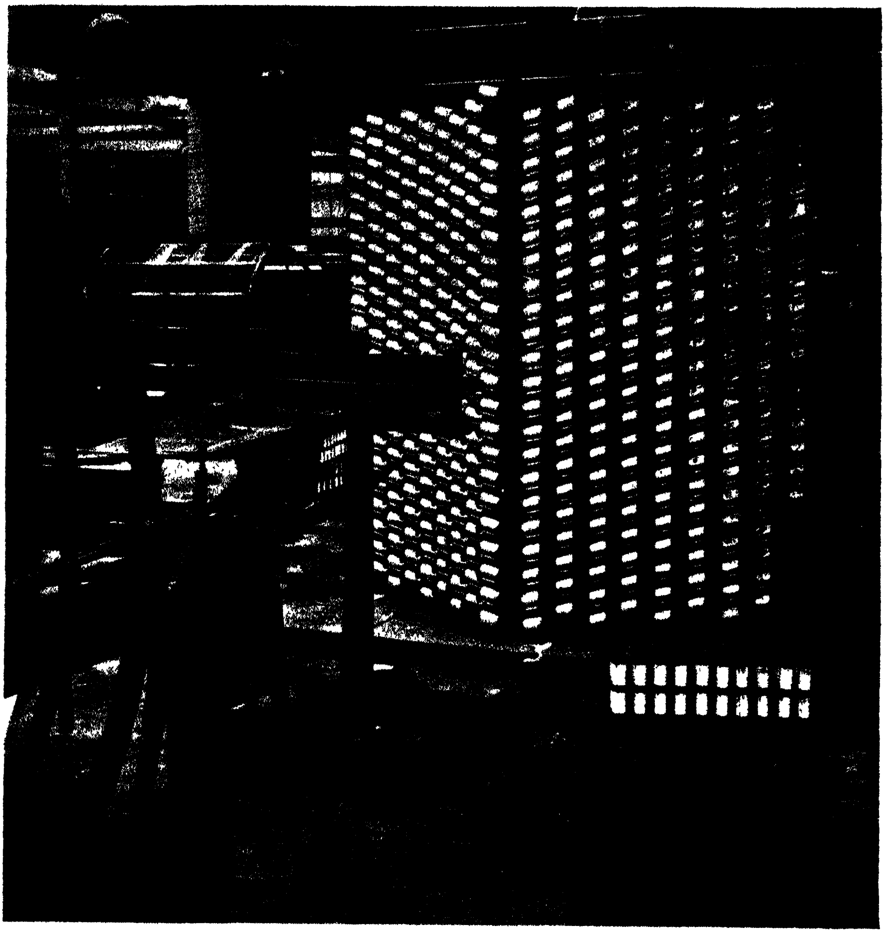


FIG. 1

Effect of Crêpe Twist on Strength and Elongation

Usually the effect of very high twisting to give crêpe effects in cloth is associated with a considerable reduction in strength of the yarn. In the case of all crêpe threads the degree of twist exceeds and goes far beyond that which produces maximum yarn strength.

Warping and Beaming Silk and Rayon Crêpe

Bobbins which have been filled with crêpe yarn and have been subjected to a steaming process for setting the twist are transferred to the warping process on specially prepared bobbin boards. These are provided with pegs for the bobbins and may support two or three bobbins on top of each other and thus prevent damage being done to the yarn in transit.

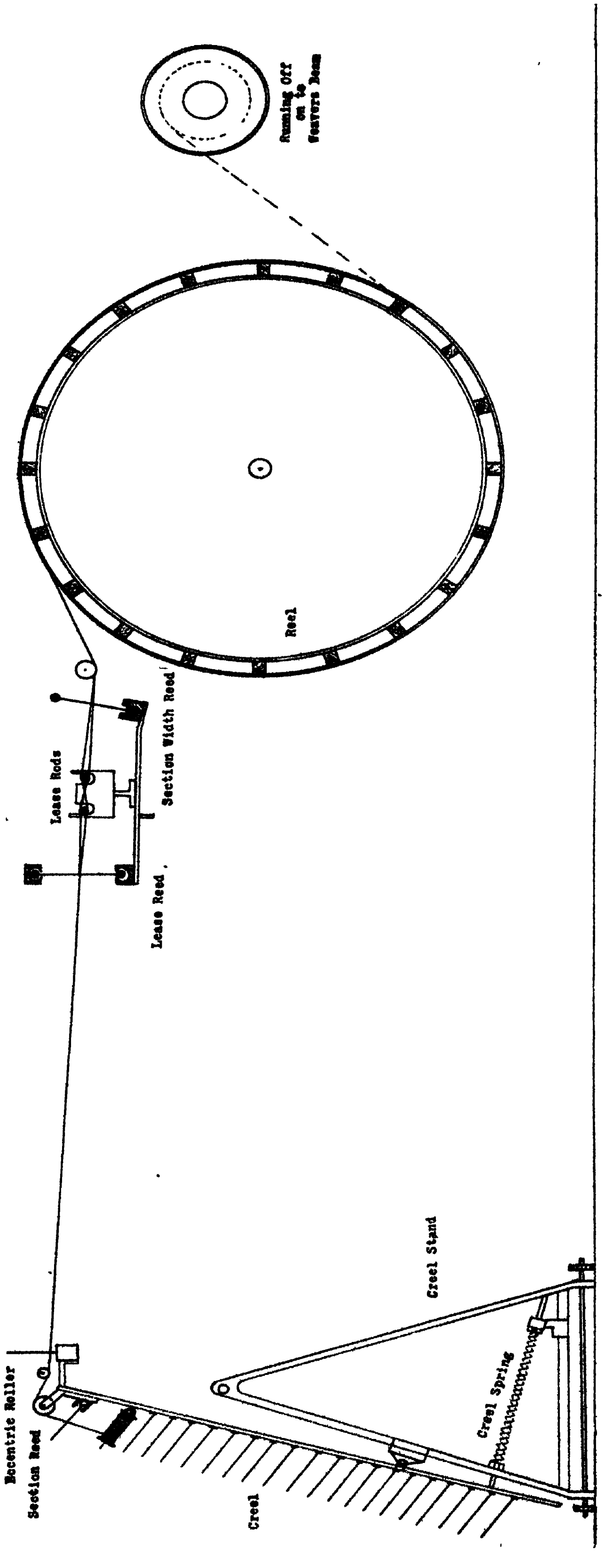

Running Off on to Weavers Beam
Reel
Section Width Reed
Lease Rods
Lease Reed
Eccentric Roller
Section Reed
Creel
Creel Stand
Creel Spring

FIG. 3

The machine which is almost universally adopted for warping silk and rayon crêpe yarns is the horizontal sectional warping machine. The essential features of this machine are—

1—Creel to hold the bobbins.
2—Large reel upon which the warp is made in sections.
3—The winding-on or beaming mechanism, which unwinds the warp off the reel on to the weavers' beam.

The number of threads required in the weaver's warp are obtained by making a number of sections side by side on the reel all of the same number of ends and length of warp. For example, if a warp of 8,400 ends of two-thread, 13/15 denier crêpe, 745 yards long was required, this would probably be made from 21 sections or bands of 400 ends each, if 400 bobbins was the limit of the capacity of the creel. With a creel of a capacity of 600 bobbins, it would be produced from 14 sections of 600 ends each. It is necessary in many cases to make a smaller section for the last one to obtain the required number of ends and width of warp on the reel. Any special selvedge threads are added to the first and last sections only.

Fig. 1 shows a machine equipped with a V-type creel which is used extensively for ordinary silk and rayon warping and also for crêpe yarn. The creel shown holds 406 bobbins; 10 rows of 23, and 8 rows of 22. It is usual in silk and rayon crêpe warping machines to employ fixed creel pegs, these enable suitable forms of braking the bobbins to be employed to keep the yarn under control and free from snarling. The pegs are set in an inclined position, so that the bobbin falls by its own gravity to the bottom of the spindle. Fig. 2 shows details of the creel peg and method of braking the bobbin to prevent over-running. Each peg A is fixed to the upright and is provided with a small hub E, a felt washer D, and a small metal washer C. The pressure of the bobbin flange against the washer and felt provides the necessary braking action to the bobbin. The amount of drag to be placed on the yarn will vary with the counts, and character of the yarn. In some cases it becomes necessary to place the iron washer on top of the bobbin to increase its weight and pressure on the felt. With very fine single crêpe yarn, light bobbins, and a light type of felt are used. In place of felt washers long strips of felt may be employed to fit the full length of the creel upright, and these can be changed quickly when required.

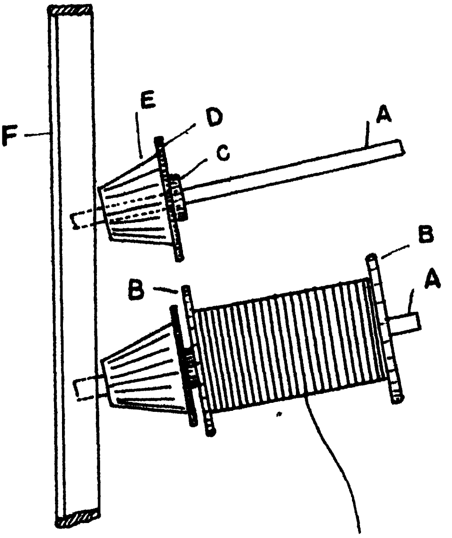
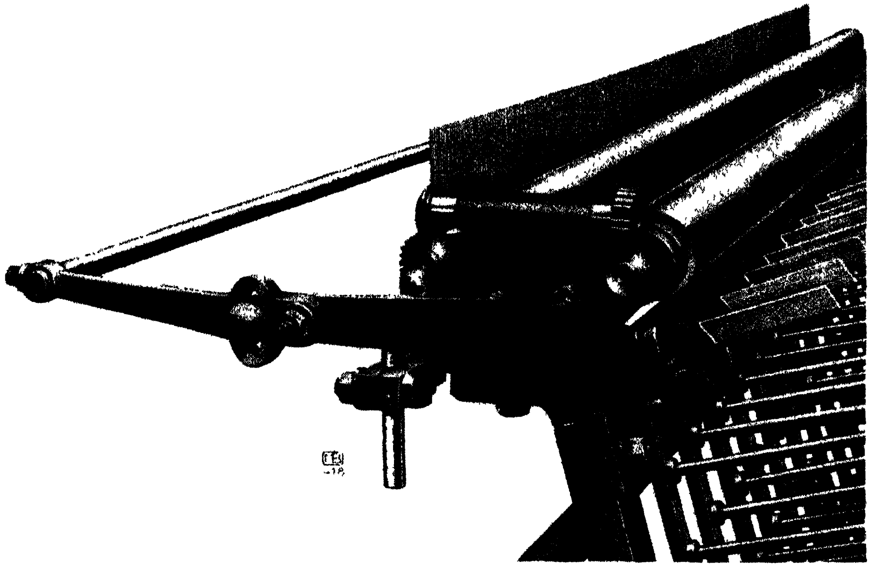


FIG. 2

Fig. 3 shows the passage of yarn through a machine equipped with a special type of inclined creel designed purposely for warping silk and rayon crêpe. There is one bank holding from 200 to 600 bobbins according to its capacity. It has been designed so that the tension can readily be adjusted to suit the denier and strength of the crêpe. The uprights supporting the creel pegs are staggered, so the thread from one bobbin will not foul the threads from the neighbouring bobbins. Each thread is kept separate from the others by a sectional reed set in an inclined position. The threads pass over a roller and under a roller which moves eccentrically, through the dents of the front comb, each dent being covered by a glass sleeve. The eccentric roller lifts the ends up and down, slowly, reducing friction in the reed, and assists in reducing magnetic or electric action. Details of these parts are shown in Fig. 4.

The whole creel bank is mounted on a pivot fixed to the stands. At the base of the creel are series of springs which have a cushion effect. When the machine starts up, the pull of the yarn at the top of the creel bank causes the creel to be drawn forward, reducing the tension on the threads at the commencement, until the bobbins commence to revolve. When the machine is stopping, the creel moves backward through the pull of the springs, thus keeping the threads under control until the bobbins become stationary. This avoids the formation of snarls and, of course, end breakages which result from their formation and entanglement with other threads.



After leaving the creel, the threads pass singly through the dents of the lease reed, through the lease rods, and are then condensed to the width of section required by a narrow reed through which the ends are drawn in 2's, 3's, or 4's, according to the number of ends in the section and its width. The beginning of each section warp is made fast to a hook on one of the horizontal bars of the reel, the section being guided if necessary by a roller; but this is not always used.

An end-and-end lease is formed in each section warp by raising and lowering the lease reed and a lease band inserted. The warper keeps all lease bands in successive sections in one straight line so that a common lease band may be inserted through the warp. When running the sections, only one lease rod must be left in, this keeps the warp separated and prevents many smashes.

During warping the reel is turned anti-clockwise, as the layers of threads are wound one upon another until the required length of warp has been run on. The Sectional reed which controls the section warp is given a slow lateral movement to the left to prevent the threads from piling upon each other. To support the sides of the section and prevent the edges from falling over, the first section is supported by means of an inclined support fixed to each bar of the reel. The inclination of this piece can be adjusted. This is indispensable for warping long lengths of course denier yarn. The side of the first section made is supported on the inclined piece and the sides of successive sections supported by the previous one.

When preparing crêpe warps, extreme care has to be taken to ensure correct joining up of the sections. Faulty joinings result in variation in tension on the warp threads when run on to the beam and show up in the finished woven fabric. On the latest type of machine a device is fitted which will ensure that the slide carrying the section reed and lease rods is moved the exact distance required after the completion of one section and before the commencement of the next one.

Machines are made with various sizes of reels. Common sizes being 2½ metres for fine silk, and 4 metres for the coarser types of rayon yarns. The reel can be started, moved backwards and stopped by means of pedals conveniently arranged alongside the machine, leaving the warper's hands free for handling and giving attention to the threads as necessary. A measuring device is fitted to count up to 1000 yards, and a stop motion provided to stop the machine at any predetermined length, for the insertion of lease bands. When all the sections on the reel have been completed the warp is then ready for transferring to the weaver's beam. The beaming of the warp is carried out at the front of the machine, the beam is mounted in a position as shown and is suitably driven. The ends of the warp from the sections on the reel are made fast to the beam barrel. The knots should be sunk into a groove cut into the barrel or into recesses. A good plan is to have hooks sunk into recesses to which are attached the ends of the warp.

As the warp threads are being pulled off the reel, and wound upon the weaver's beam, the beam is given a slow lateral movement in the opposite direction to that given to the sections, so that the beam will follow the warp on the reel. In addition, a small oscillating movement is given to ensure a slight crossing of the threads on the beam.

It is desirable with crêpe warps to place lease bands in at fairly frequent intervals, these enable weavers to straighten up the warps much better should any threads have become crossed. The machine is also used for the warping of fine cotton and worsted crêpe warps.

Crêpe warps being composed usually of right and left-twisted threads, a band should be placed between these two kinds of twist at the completion of the warp and left in until the warp has been finally gaited at the loom. This enables the overlooker to place a rod in between the two kinds of twist to separate them as they leave the weaver's beam, and pass forward to the lease rods. This rod helps the weaver to separate the two kinds of twist and keep the warps straighter. To keep the ends from twirling round each other a strip of adhesive tape laid above and below the sheet of warp threads at the end of the warp will assist the loomer or twister to pick out the threads better and with less risk of mistake.

Preparation of Hard-Twisted Cotton Crêpe Yarns

There has been, during the past few years, an extensive demand for cotton yarns with very high twists, in counts ranging from as low as single 16's up to 80's or even 100's; also in two-fold yarns of similar resultant counts. The number of turns given to the yarns often reaches as high as $\sqrt{\text{counts}} \times 9{\cdot}5$, or 10. With such high twists, the yarn becomes very snarly, hard and brittle. It also suffers a loss in strength, the maximum strength of a yarn being in the neighbourhood of $5{\cdot}5$ to $6 \times \sqrt{\text{counts}}$. The production of these high-twisted cotton yarns has led to difficulties not associated with the winding, beaming, and weaving of ordinary yarns.

Winding—Extra care is necessary in winding cotton crêpe yarn because of its hard brittle nature and its tendency for excessive snarling when the tension is periodically relaxed from the thread. Proper methods of conditioning and setting the twist in the yarn prior to winding and beaming will help to reduce the free snarling twist considerably. Several methods of conditioning cotton are practised, but the most satisfactory is steaming. One method consists of submerging the bobbons holding the yarn into a tank containing boiling water and leaving for about 12 minutes, or until it has been penetrated. As the yarn is very hard on the bobbin it takes a considerable time to obtain thorough penetration of the boiling water through the yarn. After conditioning the yarn is allowed to drain and is then ready for being wound in the course of a few hours.

With coarse counts of yarn, winding from the side of a ring bobbin assists in keeping the thread tension under better control. With this method the tension on the thread is not relaxed periodically as when winding takes place over the nose. The weak and brittle nature of fine counts of crêpe yarn does not enable them to withstand the tension and variation in tension which arise in side winding. The greatest difficulty is experienced when winding crêpe yarn with excessive turns, over the nose, as immediately the tension is released the thread snarls. A novel and patented method of controlling the tension and balloon of yarn as it unwinds is shown in the diagram Fig. 5. This consists of a circular disc of flannel stitched on to a wire ring with a series of radial slits cut into it from the hole in the centre; these form a series of flaps which rest on the chase of the ring bobbin and by their gentle pressure restrain the yarn from coming off too freely, preventing snarling and sloughing-off. The flannel ring will fall by its own gravity as the bobbin empties. Stationary guides, such as fixed flannel boards should be avoided as the passage of the yarn over these surfaces causes the twist to creep in the thread. A good ball or washer tension device is the most suitable form of tension, as the ball or washer moves with the running thread.

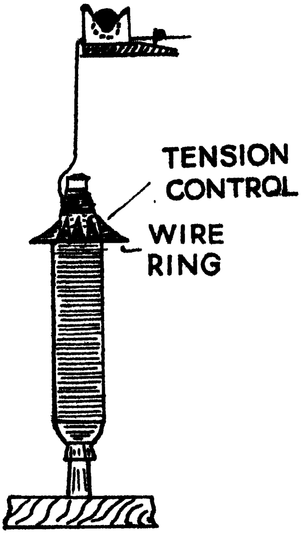


FIG. 5

If two kinds of twist are being wound, and are not tinted in contrasting colours with some fugitive dye, care must be exercised in winding not to get these mixed. They should be wound on separately coloured bobbins or marked with crayon.

Beam Warping—Attention should be paid in the first place to the warpers' beams. These should be perfectly true with even pikes and flanges so that they may run steadily and true in the beam warping frame and in the running-off machine. Any crevices between the beam flanges and the beam barrel should be filled in. The ordinary beaming frame employed in warping cotton yarns is usually equipped with a V-type of creel. While this is not the ideal type for crêpe yarns, quite good results can be achieved if care is taken in the method of creeling, using good creel pegs and steps. In many cases a spring brake is an advantage to prevent overrunning. The inclined creel of the Continental type can be used in place of the V-creel to advantage as the fixed creel pegs allow better opportunity of braking the bobbin and tensioning of the threads.

In warping fine cotton crêpe yarns where excessive tension is placed upon the threads by badly-polished creel pegs, these can be improved considerably by boiling for about an hour in linseed oil. They will then have a surface equal to that of glass.

The speed of the machine should be reduced to about 40 or 50 yards per minute, and a good brake applied to prevent the machine turning over too far when stopped. Lost ends are difficult to find as the yarn beams so hard, and turning back often gives difficulty through snarling behind the back reed and causes smashes.

The hard surface of the yarn on the beam often causes slippage in driving between the yarn surface and driving drum. The friction between the two surfaces can be made more effective by covering the wood driving drum with swansdown, listing, or a light felt fabric similar to that used on winding machine drag boards.

Care must always be taken when piecing up broken ends or in creeling to prevent the formation of slack ends and snarling behind the reed. The dents of the expanding reed should be evenly and well spaced to minimise any variation in the tension of the threads and to produce a perfectly level beam which will well repay the care taken in the good running-off in the dry taping machine afterwards.

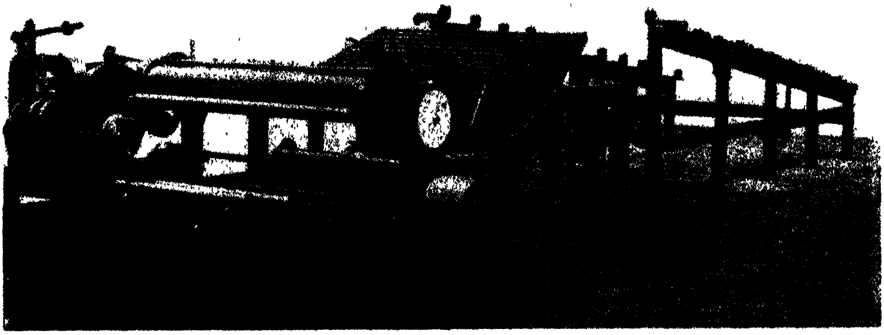


FIG. 6

Beaming or Running on of Cotton Crêpe

It has been the general practice in the cotton manufacturing section of the cotton industry to weave highly-twisted cotton yarns, such as those prepared with a number of turns per inch, equal to 8 to 10 × $\sqrt{\text{counts}}$, without any previous sizing. Such threads are usually sufficiently well-twisted, and strong enough, to withstand the strains and friction of weaving without being sized. The back beams should be prepared no wider than the threads are to occupy on the weavers' beam. The general method employed of running the yarn from the back beams on to the weavers' beam is by the system known as dry-taping or running-on. The process consists of collecting the several sheets of threads from their respective back beams, combining them together to form one sheet and running them on to the weavers' beam.

A dry-taping machine consists of a headstock, or the running-on part of a wet-taping machine, combined with a creel to hold the back beams. Fig. 6 is a machine specially built for running crêpe warps. Several types of creels are employed, but for crêpe yarns the inclined type shown is usually preferred, as this allows the threads from the respective back beams to be kept quite separate from each other. The creel shown in Fig. 6 will take up to 10 beams, and the slope is from front to back. Another type is that shown in Fig. 7, with the inclination from back to front which is sometimes preferred. The sheet of threads from their respective back beams as illustrated in Fig. 8 are kept quite separate from each other by means of dividing rods in the headstock. These are also set in an inclined position and at such a spacing that they will keep each thread separated from one another in the dents of the expanding comb. In each dent of the reed there must not be more than four or six ends, and the reed must be constructed of fine steel wire and of a suitable counts to enable the total number of ends to be placed in without crowding them together in the dents. Placing of large numbers of ends in each

FIG. 7a

dent will only lead to trouble in weaving-off, through ends rolling over and becoming crossed. Tight and slack ends through the formation of a ridgy beam, are a source of annoyance in crêpe yarn, as the slack ends snarl and twirl. They become fast at the loom lease rods, breaking out other threads with them. It should be the aim and object of the dry taper to secure a firm and level weaver's beam with the same degree of tension on every back beam, and also warp threads to secure good weaving-off qualities. Any tendency for the threads to turn or roll over each other must at once be avoided. Each back beam must be well braked, run steadily and evenly; the speed of the machine must be reduced from that employed when running ordinary yarns. The spreading rods at the front of the machine should be used and oscillated to maintain a flat sheet and to prevent the threads from rolling.

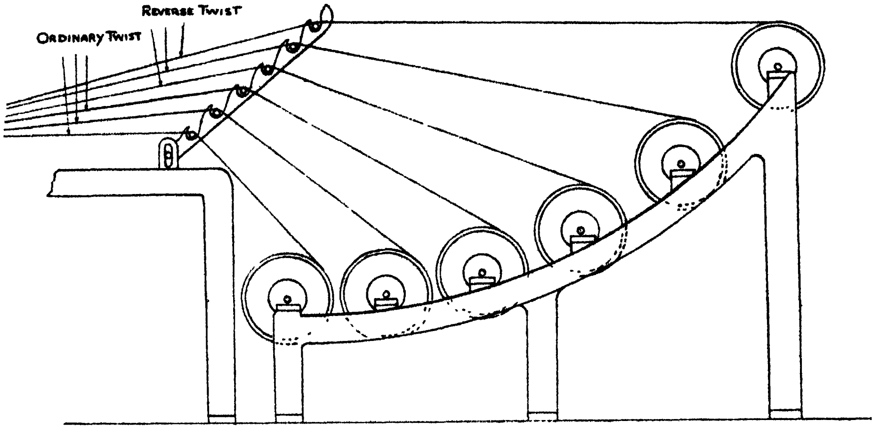


Fig. 7

To keep the two kinds of twist separate and apart from each other, the reverse twist is kept above the ordinary twist. Just before the operative doffs the warp, he should place a band between the reverse and ordinary twisted yarns to separate them. He should then pick an end-and-end lease with the two kinds of twist arranged to their correct pattern required, which is usually 1 and 1, 2 and 2, 4 and 4, etc. The tape separating the two kinds of twist must be kept in position during looming or twisting and left in for the overlooker until he has gaited the warp in the loom. The band enables him to place a rod between the two kinds of twist as the warp leaves the weaver's beam and passes to the lease rods. The expanding reed must be deep so that the sheet of threads will be kept well apart; many prefer to use a reed in which the dents are slightly inclined so that the threads can lay side by side better without piling up on top of each other. A reed of this kind prevents the threads from rolling over between the reed and the measuring roller.

Looming and Twisting

The operation of looming and twisting highly-twisted crêpe threads often presents considerable difficulty to those not usually associated with this kind of warp yarn. The snarly nature of the yarn makes it difficult to pick the threads out from the lease rods, and to do so requires the threads to be kept under very heavy tension. To prevent the threads from snarling excessively, and twirling round each other at the end of the warp, several different methods may be adopted. One good method is to place a strip of adhesive tape across the full width of warp threads while under tension in the running-on process and before the warp is doffed. This will keep the threads in their relative positions and prevent them twirling round each other. Another method sometimes used is to kill the effect

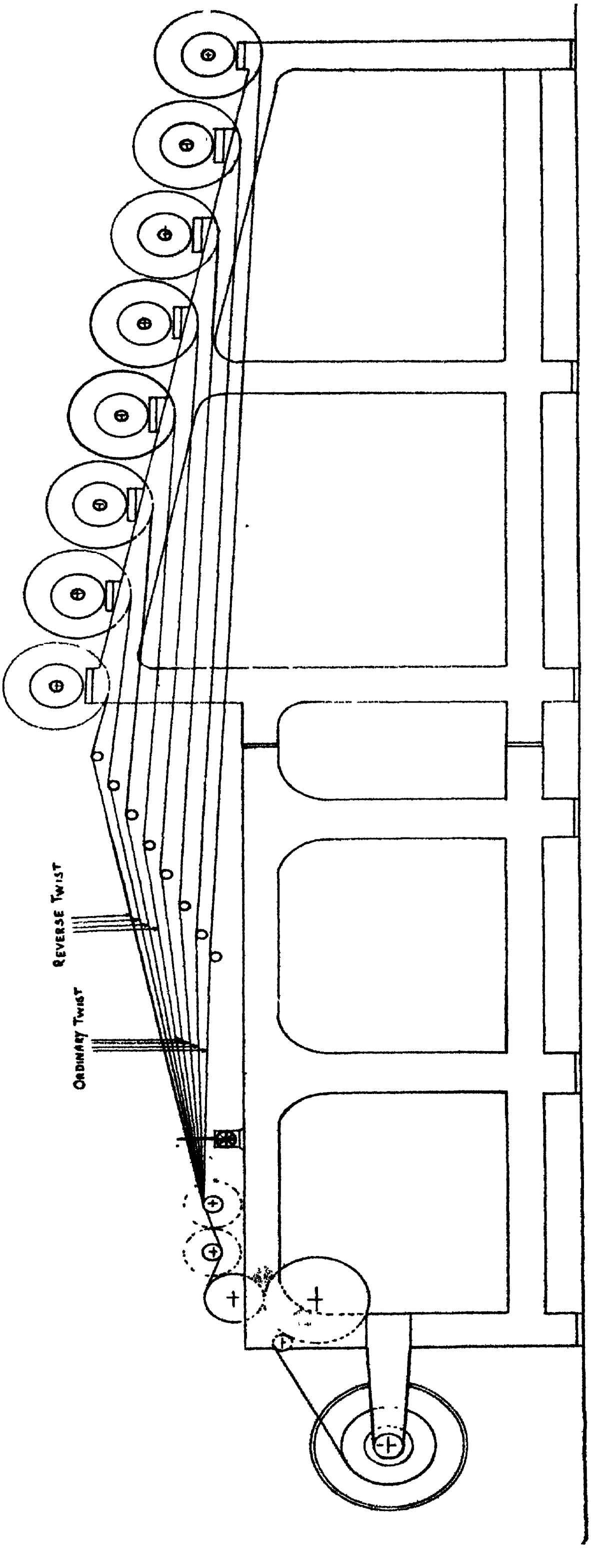


Fig 8

of the twist at the end of the warp by brushing over a light size paste for about half a yard at the warp end; the size, when dry, prevents snarling and twirling round.

In some cases, particularly in fine silk and rayon crêpes, it is necessary to twist the warps in the looms, especially where stop motion wires are being used. The healds and other parts then need not be disturbed. The warp can be gaited up much easier this way than if the healds and reeds are taken out and twisted away from the loom. Crêpe warps are also difficult to pin with stop motion wires in the loom. By a special method, warps can be successfully twisted out of the loom and the stop motion wires left on if reasonable care be employed. Fig. 9 shows an arrangement for twisting crêpe warps where stop motion wires are left on the ends of the old warp. The wires are clamped to the healds by special bars inserted into the slots of the wires which keep them in position. A long lap of old cloth is left on in front of the reed and lease bands put in with a strip of adhesive tape fixed on the sheet of threads while under tension in the loom. The new warp can then be twisted to the warp healds and stop motion wires, and then taken to the loom to be gaited. This method saves the time needed to drop the pins over the ends in the loom afterwards which is a slow process. When looming crêpe warps only short lengths should be wound off the beam to loom through the healds.

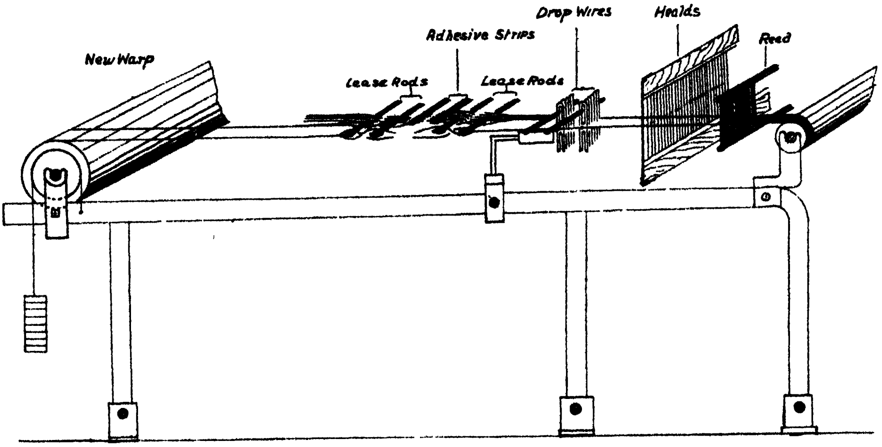


FIG. 9

Pirning Crêpe Yarns

Pirning highly-twisted threads of silk, rayon, cotton, or worsted calls for a considerable amount of skill and dexterity on the part of the operative winder. Persons who have had years of experience in the winding of normal-twisted yarns usually find some difficulty in winding yarns with crêpe turns. The yarn is more difficult to handle and piece up because of its snarly and brittle nature. It is necessary to maintain the thread under constant tension to keep out snarls. Silk and rayon crêpe is usually supplied on flanged bobbins, while worsted and cotton crêpe is often supplied on cheeses. The method of pirning, therefore, in all cases is from an unrolling bobbin or cheese supply which is the most suitable form as the tension on the thread is constantly maintained and reduces the tendency of the thread to snarl.

Fig. 10 shows the usual arrangement of mounting the supply-bobbin or cheese in a Schweiter Seta-Rapid pirn winder. The supply-bobbin spindle is carried in a simple fashion and can easily be placed in position or removed from its bearings. The braking of the bobbin is by a patented adjustable strap of webbing pressing on the underside of the hub of the spindle. It is readily adjustable for winding

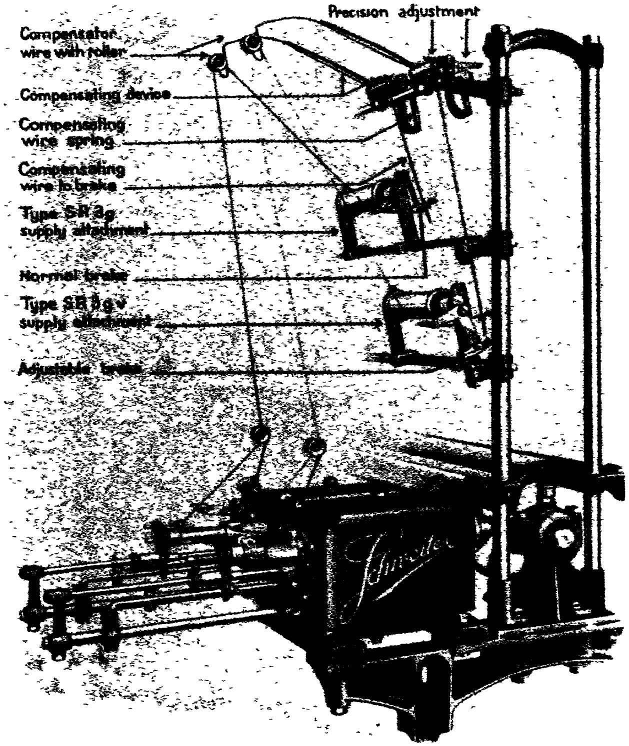

Precision adjustment
Compensator wire with roller
Compensating device
Compensating wire spring
Compensating wire to brake
Type SR 3g supply attachment
Normal brake
Type SR 3g v supply attachment
Adjustable brake

Fig. 10

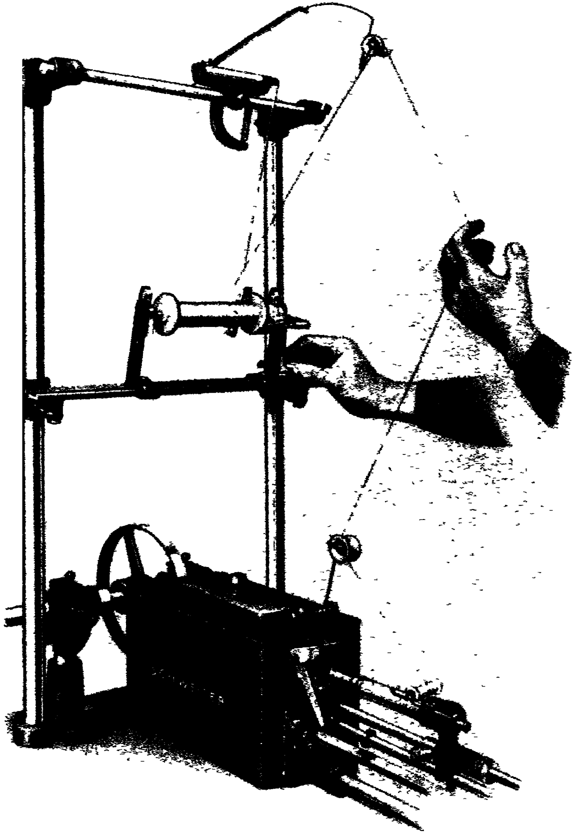


Fig. 11

either fine or coarse counts of yarn. The pressure of the brake can be automatically controlled by a wire operated through the compensating wire, so that when the tension on the yarn is greatest the pressure of the brake is relieved and *vice versa.*

To maintain a uniform supply-bobbin speed most machines are equipped with compensator spring yarn guides. These assist in winding the yarn at a more uniform tension by compensating for the variable yarn speed which, through the varying diameters of the pirn chase always takes place on pirning machines with a constant spindle speed. Even the best regulated compensation does not maintain absolute uniform tension. The braking load applied to the unrolling bobbin supply requires careful control. If too excessive, there is danger of the yarn being strained, if too small, the supply-bobbin may over-run itself when the traverse is changing its position from the shoulder to the nose of the pirn. If tension is relaxed periodically on crêpe yarn through over-running, or any other cause, snarls are liable to be formed which are difficult to remove even by tension.

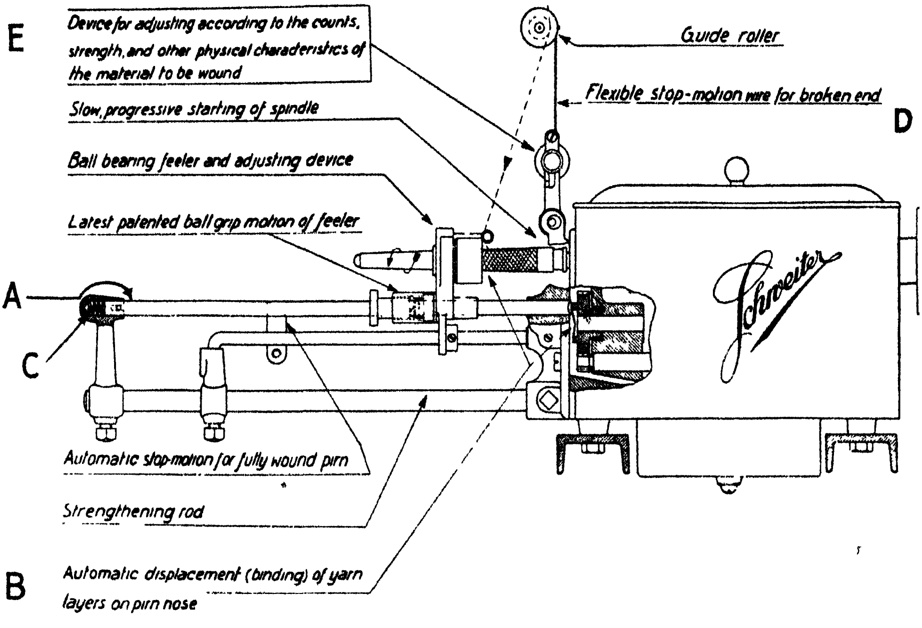

E
Device for adjusting according to the counts, strength, and other physical characteristics of the material to be wound
Slow, progressive starting of spindle
Ball bearing feeler and adjusting device
Latest patented ball grip motion of feeler
Guide roller
Flexible stop-motion wire for broken end
D
Schweiter
A
C
Automatic stop-motion for fully wound pirn
Strengthening rod
B
Automatic displacement (binding) of yarn layers on pirn nose

FIG. 12

Under the most ideal conditions, with the compensator working correctly, there is variation in tension during winding between the shoulder and nose of the pirn. The greater the difference between the diameter of the pirn nose and shoulder, the more variation in tension there will be in winding. For crêpe yarns the difference between the size of the tube and the diameter of the pirn should be kept as small as practicable; $\frac{1}{16}$ in. for the nose and $\frac{14}{16}$ in. for the shoulder, which gives a winding speed ratio of 2:1, are found to be quite suitable for rayon, silk, crêpe, and cotton both from the point of view of winding and weaving.

The tension placed upon a thread when starting up the spindle at full speed is much too great when winding fine counts of crêpe yarn. A progressive starting motion is a decided advantage. Even with this it is advisable to run machines winding crêpe at a much slower speed than that employed when winding normal yarns. The Seta-Rapid machine illustrated in Fig. 11, equipped with a slow-starting device, shows the method employed when starting up the spindle. The right hand adjusts the yarn tension, preventing the formation of snarls, and releasing the band brake, while the left hand is used for control of the spindle

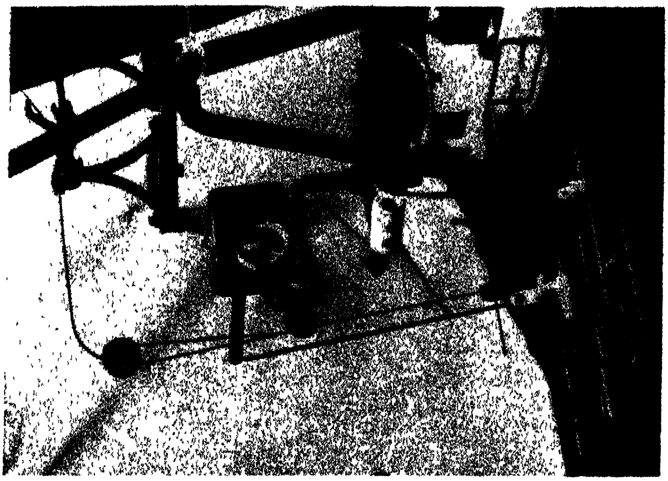


Fig. 16

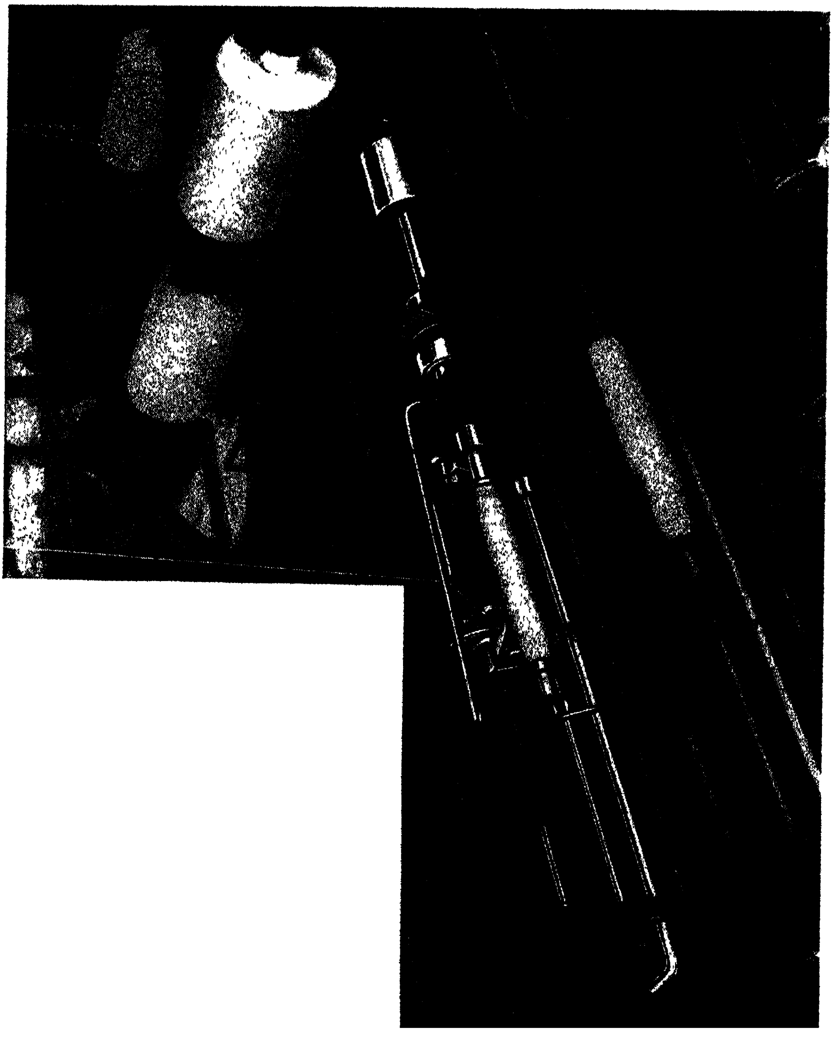


Fig. 13

and the tension of the running thread. The slow start allows the inertia of the supply bobbin to be overcome gradually without sudden deflection of the compensator wire, and straining or breaking the thread.

Fig 12 shows details of the essential parts. The shape of the pirn is obtained by the use of a fibre-shaper cup run on a ball race in a housing. This type of bearing feeler eliminates friction, injury, or polishing of the yarn. The spindle, in addition to the rotary motion, is given a quick backward and forward movement by means of a cam, this forms the traverse; the ratio of spindle speed to traverse is 14:1, winding seven coils up and seven down the pirn chase. On each forward thrust of the spindle, the pirn enters the cup, causes the latter to revolve, theoretically at the same speed as the pirn. By reason of the sensitive bearing, the cup continues to revolve as long as the pirn enters the cup, so any danger of chafing of the yarn is avoided.

The builder motion is anchored to a shaft A which receives a small reciprocal motion by a face cam B, the backward thrust being obtained by a coil spring C. The winding spindle which revolves at a much greater speed than the shaft carrying the builder-motion, causes displacement of the yarn layers on the nose of the pirn. This binds and locks the layers firmly, without resort to either excessive thread tension or a nose tension hardening motion, a most desirable arrangement for fine and tender crêpe yarn. Less tension can be employed throughout, and softer pirns wound without fear of any sloughing off, or stretching the thread. In addition to passing over the ordinary compensator wire guide pulley, the thread passes over a pulley mounted on the flexible stop motion wire D This in a way serves as an additional compensator. Increases or decreases of tension can be obtained, up to a point, by turning the serrated wheel E.

The adjustable supply-bobbin brake enables the operative to determine the tension herself, by simply moving it backwards or forwards. For crêpe yarns one of the most important features is the flat bar running along the top of the compensator wire. In compensation a jerky movement often occurs which strains and often breaks down the thread, but this device acts as a damper and prevents jerky movement, giving a much steadier and uniform wind.

In the case of the No 90 Universal pirning machine, a gradual start of the spindle can be made by using a light type of spindle clutch spring and an adjustable split collar which the driving gear thrusts against leaving a clearance of about ·02 in.

Expert winders can, by a little dexterity, obtain a good start-up without stretching or breakage of the end by starting the spindle slowly with the left hand, pressing the clutch gently into gear and watching the compensator wire deflect by the sudden rush of tension. As the supply bobbin begins to move and the wire to rise, the operative presses a finger lightly on the hub of the bobbin-supply spindle to brake it. This will prevent over-running and forming snarls and also prevent the compensator wire from beating too quickly and breaking the end. By gradually reducing the breaking of the supply-bobbin as the compensator begins to synchronise with the traverse many end breakages will be saved. Simple as such an operation may seem it requires a little patience and practice to acquire perfection which is so important in pirning crêpe.

A slow starting device has now been evolved which can be fitted to all No. 90 pirning machines, this meets a long-felt want in pirning the finer silk and rayon crêpe. An illustration of a spindle fitted with this device is shown in Fig. 13.

Variable Spindle Speed Pirning Machine

To overcome the large variations in tension, through winding on to a variable diameter of pirn running at a constant velocity, machine makers have endeavoured from time to time to devise a variable spindle drive which will give a uniform yarn speed. The variation in the winding-on diameter of a pirn causes a fluctuation of demand in proportion to the difference in diameters between the nose and shoulder of the pirn. As these normally vary in the ratio of about 1:2, the tension variation is considerable. Variable spindle drives are now being fitted to Seta-Rapid pirning machines, a diagram of the gearing being illustrated in Fig. 14. The general arrangement of the parts is similar in all other respects to the ordinary Seta-Rapid pirning machine.

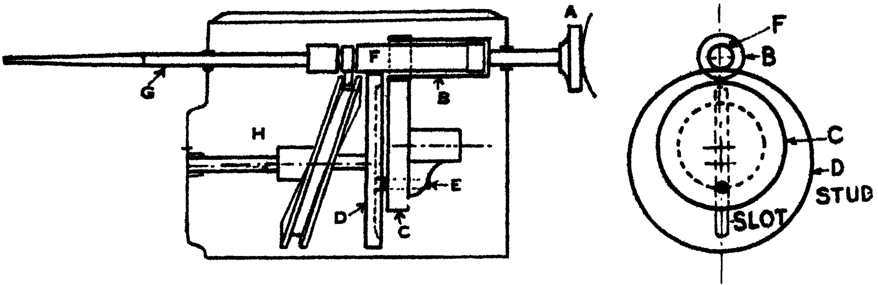


FIG. 14

The friction wheel A is not directly coupled to the spindle but to a hollow sleeve B which carries a 19-tooth wheel. This drives wheel C, with 95 teeth, carrying stud E projecting from its face. This stud rides in a slot cut in wheel D, with 122 teeth, and drives spindle wheel F which has an extended gear of 11 teeth floating in the tube shaft B. It will be clear from the relative positions of wheel-shafts C and D, that the path described by stud E will be eccentric in respect of wheel D. The speed at which wheel D and the spindle are driven will be inversely proportional to the effective driving radius at any point in the path of stud E. The fastest spindle speed will be when the stud is in the position shown. Then winding is taking place on the nose of the pirn. The slowest speed is when the stud has made a further half revolution and winding is on the shoulder of the pirn. The traverse cam being fixed on the same shaft as wheel D, its speed synchronises with that of the spindle. Diagram A, Fig. 15 shows the variation in tension resulting in winding on a machine with a constant spindle speed and diagram B the tension variation when the differential speed drive is fitted.

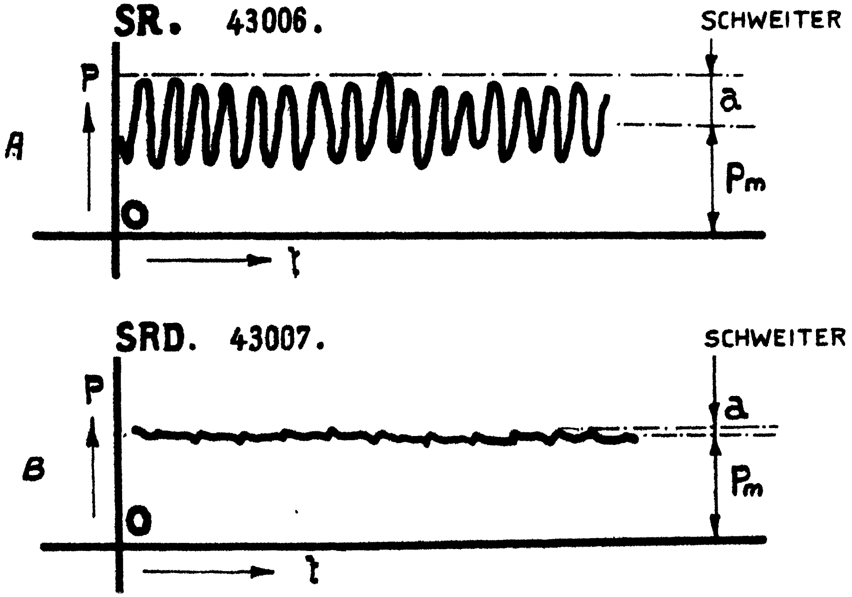


FIG. 15

Direction of Winding Crêpe on Pirn

There is considerable difference of opinion regarding the direction of winding crêpe threads on to pirns. In some cases both twist-way (right twist) and weft-way (left twist) are wound in the same direction. In others twist-way is wound weft-way and weft-way twist-way, and *vice versa.* There is no one common method. The author has found that the best results are achieved (with the twist kept in position) by winding twist-way yarn with the spindles running weft-way and *vice versa.* On a Seta-Rapid machine there are two ways of making changes in the spindle direction. One is by crossing the driving belt when all the spindles will run in the opposite direction, the other alternative is to use an extra friction wheel. This is moved to the opposite side of the friction disc which drives the spindle—a very simple operation.

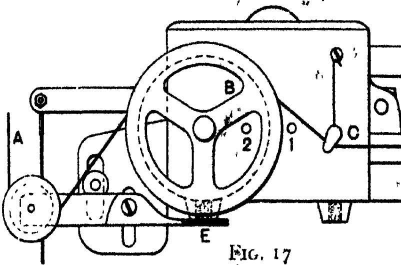


FIG. 17

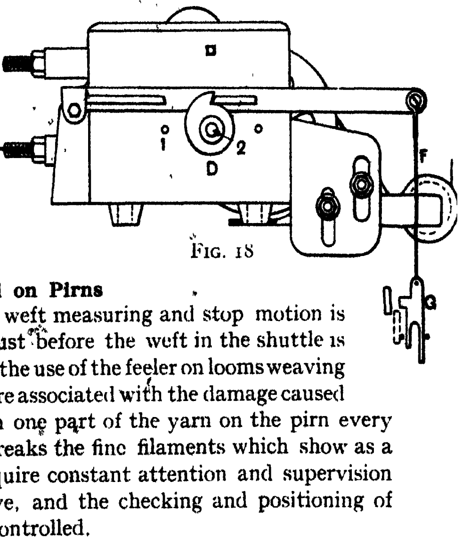


FIG. 18

Measuring the Length of Weft Wound on Pirns

As an alternative to a weft feeler, a weft measuring and stop motion is sometimes applied to a loom to stop it just before the weft in the shuttle is exhausted. There are many objections to the use of the feeler on looms weaving silk and rayon crêpe wefts. Chiefly, they are associated with the damage caused by a feeler blade constantly tapping on one part of the yarn on the pirn every two picks. This action damages and breaks the fine filaments which show as a serious defect in the fabric. Feelers require constant attention and supervision by those responsible to be fully effective, and the checking and positioning of the shuttle has to be more accurately controlled.

When a loom-measuring motion is applied in place of a feeler it is absolutely essential that the weft provided should be accurately measured. There must be the same length on each pirn for the motion to be effective.

Fig. 16 shows a spindle of a No. 90 Universal machine fitted with a measuring device. It consists of a box 4½ in. × 2 in. × 3½ in. containing the necessary gearing. Fig. 17 shows the pulley side and Fig. 18 the cam side. The gearing from the pulley shaft to the cam shaft consists of a simple train of wheels as follows—

On the pulley shaft is a single worm driving a worm wheel of 57 teeth. Fixed on the same shaft is a single worm driving another wheel of 57 teeth fixed to cam-shaft No. 1. With this gearing the pulley makes 3,249 (57 × 57) revolutions for one revolution of the cam.

The gearing is very sensitive and turned by the pull of the yarn over the pulley. The passage of the thread is clearly shown. The automatic brake stops the pulley immediately the tension is released through end-breakage or running out. A projection on the lever rests on the cam surface, and as the latter revolves the lever is raised. A wire rod connection lifts a stop piece above the drop finger. This disengages the spindle, a light spring or elastic pulls the stop piece forward on to the top of the drop finger and as it falls disengages the spindle.

There are five different sizes of pulleys numbered 1, 2, 3, 4, 5. These can be made to give 600, 700, 800, 900, and 1000 yards respectively. A gearing with a ratio of 2:1 between shafts No. 1 and No. 2 is arranged. With a cam on No. 2 shaft these lengths will be doubled. By reversing the internal gearing to give a ratio of 1:2 the lengths will be halved. In this way the device can be arranged for almost any convenient length simply and quickly. By pressure on the cam-shaft end the gearing and cam can easily be set back to zero at any time.

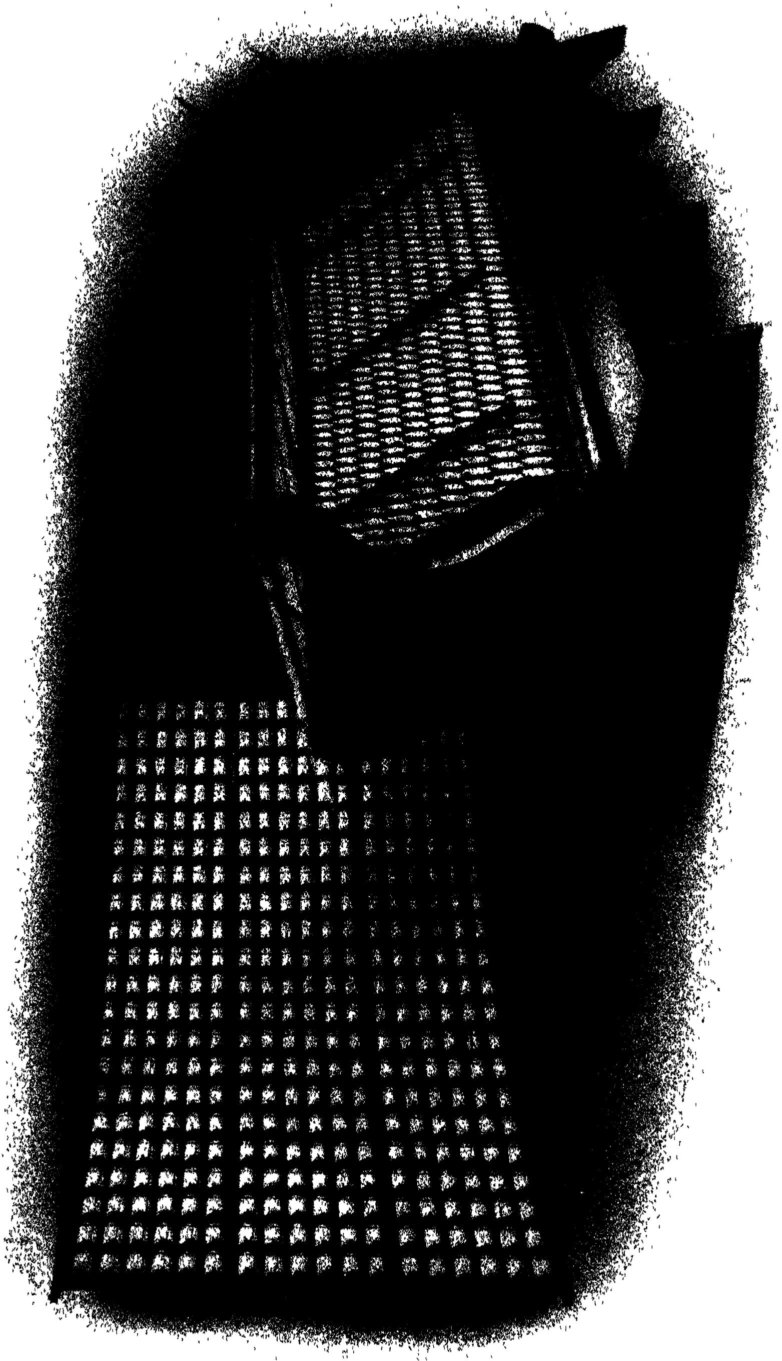


Fig. 19

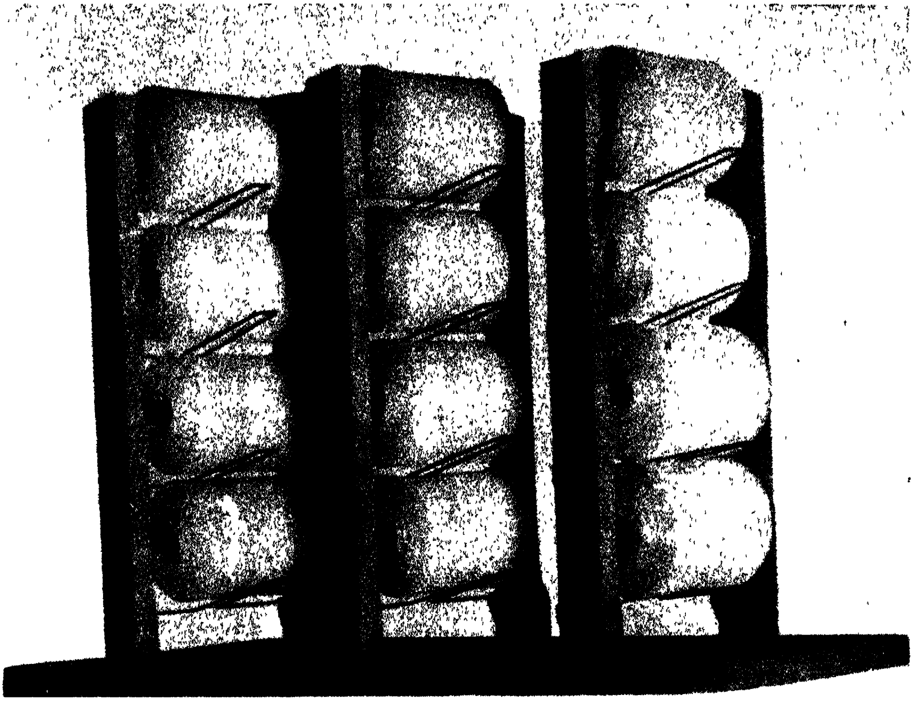


FIG. 20

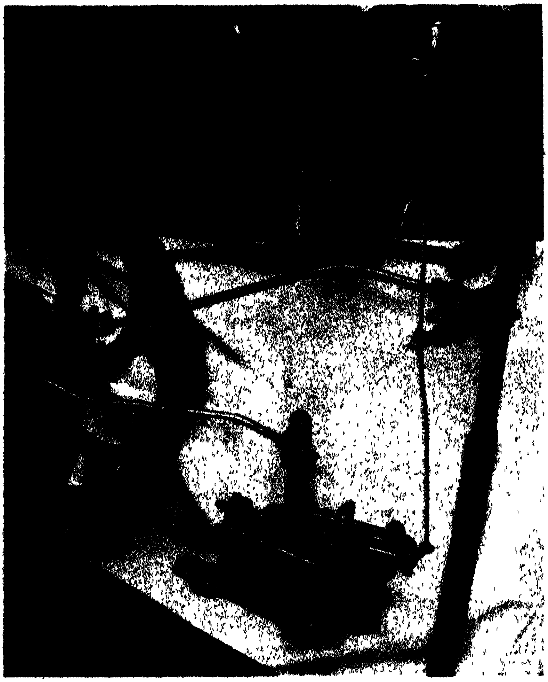


FIG. 21

Another method often employed when pirning cotton and worsted crêpe, with a definite and fixed length on each pirn, is that accomplished on a Holt's pirning machine. This machine can be adopted to pirn either from a bobbin or cheese supply or from a back beam. The latter is the better method as the yarn can be measured on the back beam previous to winding on to pirns. If necessary the pirning machine can be provided with a measuring motion which is necessary when pirning from cheeses. Fig. 19 shows the machine winding cotton crêpe from cheeses. A special form of tension brake being applied to each cheese as shown in Fig. 20.

Loom Measuring and Weft Stop Motion

Although this is really beyond the scope of this paper it is a necessary motion which works in conjunction with the pirning measuring motions described. The motion is shown fitted to a loom in Fig. 21. The box containing the necessary gearing is mounted on the loom at the driving side. Movement of the parts is obtained from the loom bottom shaft by means of the eccentric and driving rod shown. This drives a ratchet wheel, and single worm and worm wheel. The face of the latter is a clutch member formed to engage with a clutch part on the face of a disc with a slot cut in its rim, and a stop stud screwed to its face. All these are free on the shaft. Fixed to the shaft is a worm wheel which carries a stud screwed to its face. Mounted on the same stud, is a holding wheel which serves as a hand wheel for the purpose of setting the position of the stop to put in the required number of picks. One revolution of the handwheel, which contains 50 notches, represents 100 picks. The stop on the face of the worm wheel sets the limit to which the disc stop and gearing can move back, under the influence of a coiled spring, when the disc is set free.

When the notch on the disc comes directly underneath the pendant mounted on a lever, the latter falls. This is communicated to a lever mounted on the loom starting handle by a wire rod connection. The lever is brought up in position between the starting handle and a collar mounted on a rod vibrated by the eccentric on the loom bottom shaft.

The mechanism re-sets itself by the weaver lifting the wire rod connection. This disengages the clutch and the coiled spring returns the slotted disc to its starting position. Once the motion is set there is no need for further attention by the weaver providing the weft length on the pirn is uniform. By turning the handwheel forwards or backwards the motion can quickly be reset for almost any reasonable length of weft.

Crêpe Attachment—There is also provided an attachment for weaving crêpes and similar fabrics where the wefts are inserted 2R, 2L twists alternately. This stops the loom with the correct shuttle containing the almost exhausted pirn at the starting side of the loom. The weaver therefore need not turn the loom over to restart. By employing a full pirn in one shuttle and exactly a half pirn in the other, the motion will stop the loom first on one shuttle then on the other alternately. This is accomplished by mounting a slotted barrel on a stud, compounded with a ratchet wheel of 12 teeth. The barrel is slotted opposite alternate teeth only and is turned one tooth for each two picks. A second pendant is mounted on the falling lever over the slotted barrel. This prevents the first pendant from falling until the second one is directly over a slot in the barrel. Such a condition would mean that the loom would be stopped only on multiples of four picks, which would always fall on the same shuttle. To bring a slot under the pendant alternately for opposite shuttles, a stud mounted on the falling lever disengages the pawl operating the ratchet wheel fixed to the barrel. In consequence the barrel misses being turned at every stop and loses two picks. Thus a slot will fall under the pendant when the opposite shuttle has to be changed. This device can also be used on multiple box looms to operate the boxes just before the weft in each shuttle has been exhausted and this renders the loom semi-automatic.

THE PROCESSING AND WEAVING OF RAYON YARNS

with an Introduction on the Effects of Moisture Content on their Physical Properties and an Appendix of Some Typical Faults in Fabrics

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(Courtaulds Ltd.)

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INTRODUCTION

THE EFFECTS OF MOISTURE CONTENT ON THE PHYSICAL PROPERTIES OF RAYON

From the point of view of their chemical constitution, rayons may be divided into two main classes, the regenerated celluloses (viscose, cuprammonium, nitro-, etc.) and the cellulose esters (cellulose acetate, etc.). A study of their moisture relations leads to a similar classification, for the regenerated celluloses have, at all humidities, a higher hygroscopicity even than mercerised cotton, while the cellulose esters have lower hygroscopicities than ordinary scoured, raw cotton*. There are also differences in the shapes of the adsorption isotherms of the two types of rayon, but we would stress the differences in the regains of the two types and also the very great hygroscopicity of the regenerated celluloses. In the present paper, attention will be focussed on viscose and cellulose acetate as the most important and most widely used representatives of the two classes of rayon.

Before enumerating briefly the effects of the absorption of moisture by rayons on their physical properties, it may be of interest to consider the extent and magnitude of the fluctuations in relative humidity which are to be expected in a mill unequipped with a plant for controlling the humidity. Records of the relative humidity have been kept for several years in warping departments, weaving sheds, etc. in mills in Essex and in Lancashire and an analysis of the charts shows that—

(*a*) In any one week there are generally large fluctuations; instances in which the differences between the maximum and minimum relative humidities during any one week are as great as 30% or 40% R.H. are by no means uncommon.

(*b*) The mean relative humidity any one week may be as much as 15% to 20% higher or lower than the mean relative humidity of the preceding week, although the differences are usually less than this.

(*c*) There is a definite tendency for the mean relative humidities to rise from winter to summer and to fall again from summer to winter. The general level of humidity from May or June to September or October is above 60% R H., and it is usually below 60% for the remainder of the year. This general trend of the humidities is explained by the fact that in summer the mills are not heated, windows are open and the relative humidities inside and outside are the same and usually over 60% R.H. In winter, even when the outside atmosphere is very moist, the air is cold and is heated up when it enters the mill, so that its relative humidity is reduced, usually to less than 60% R.H. In summer, especially during the months of July, August, and September, humidities as high as 80% R.H. may frequently persist throughout a whole working day; at the other extreme, it is by no means unusual in winter, especially during February and March, for the humidity to be as low as 30% to 40% R.H. for periods of several consecutive days. Readings as low as 23% have actually been recorded.

Fig. 1 shows a typical analysis of the fluctuations in humidity in a particular department of a mill for a period of 12 months. The graphs give the maximum, minimum, and mean humidities observed during each week.

The high relative humidities prevalent in the summer and especially during July and August, are especially dangerous and likely to produce faulty fabrics when they are associated with the use of high tensions or large variations in

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* Urquhart and Eckersall. *J. Text. Inst.*, 1932, **23**, T163-T170; Shirley Mem. XI, 1932.

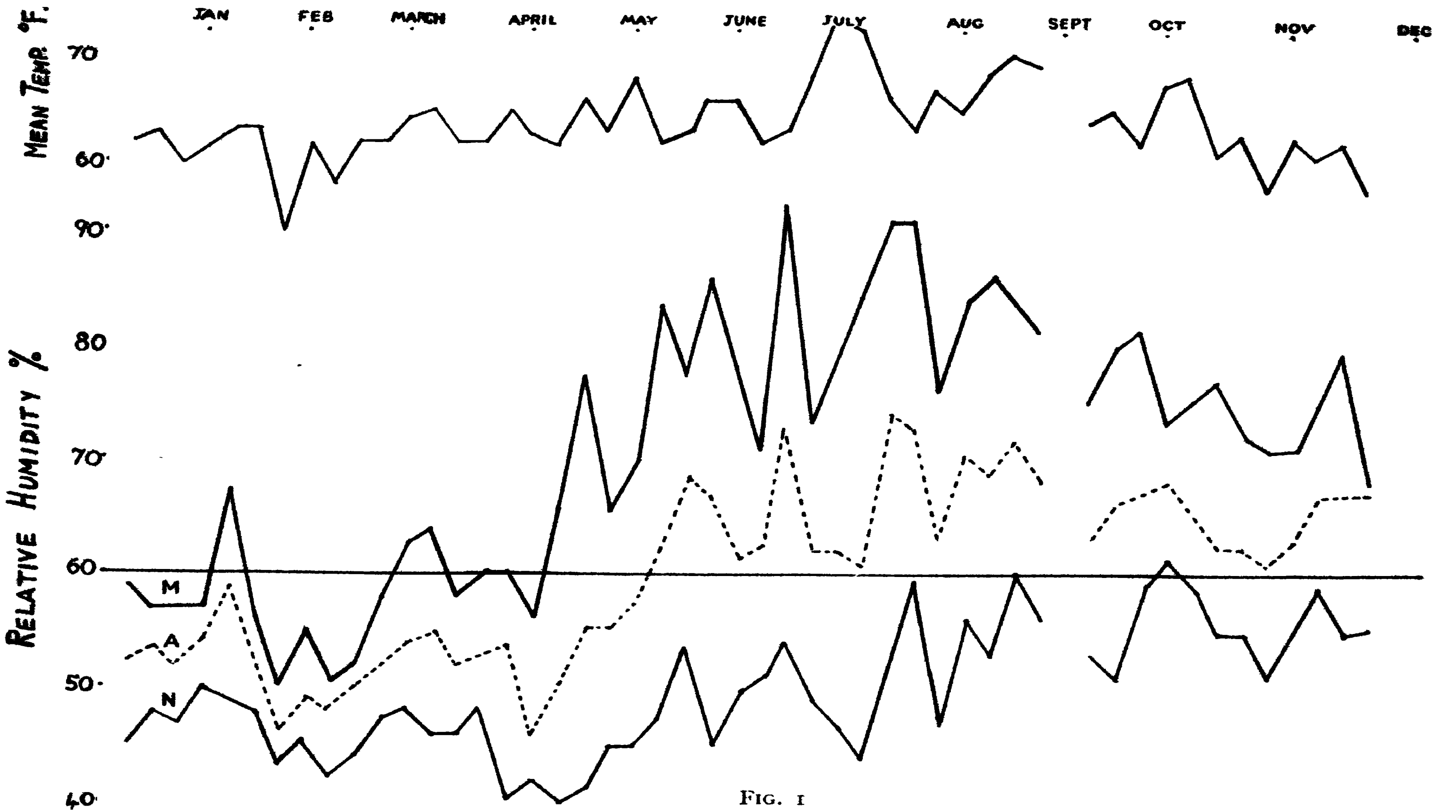

FIG. 1

M Max. Relative Humidity in Each Week.
A Rel. Humidity during Working Day, Averaged for the Week.
N Min. Relative Humidity in Each Week.

tension. In winter a probable source of trouble is the fluctuation in humidity due to fluctuations in temperature. In mills where the heating arrangements are not operating for the full twenty-four hours, there is a perceptible fall in temperature during the night and a consequent increase in relative humidity. The yarn in the looms, on the surfaces of beams, etc. absorbs moisture so that, when work is re-started in the morning, standing places, strained yarn, etc. are likely to make their appearance, until this damp yarn is used up. The only way to avoid this trouble in the mornings is to make arrangements to keep up the temperature of the mill during the night throughout the winter months.

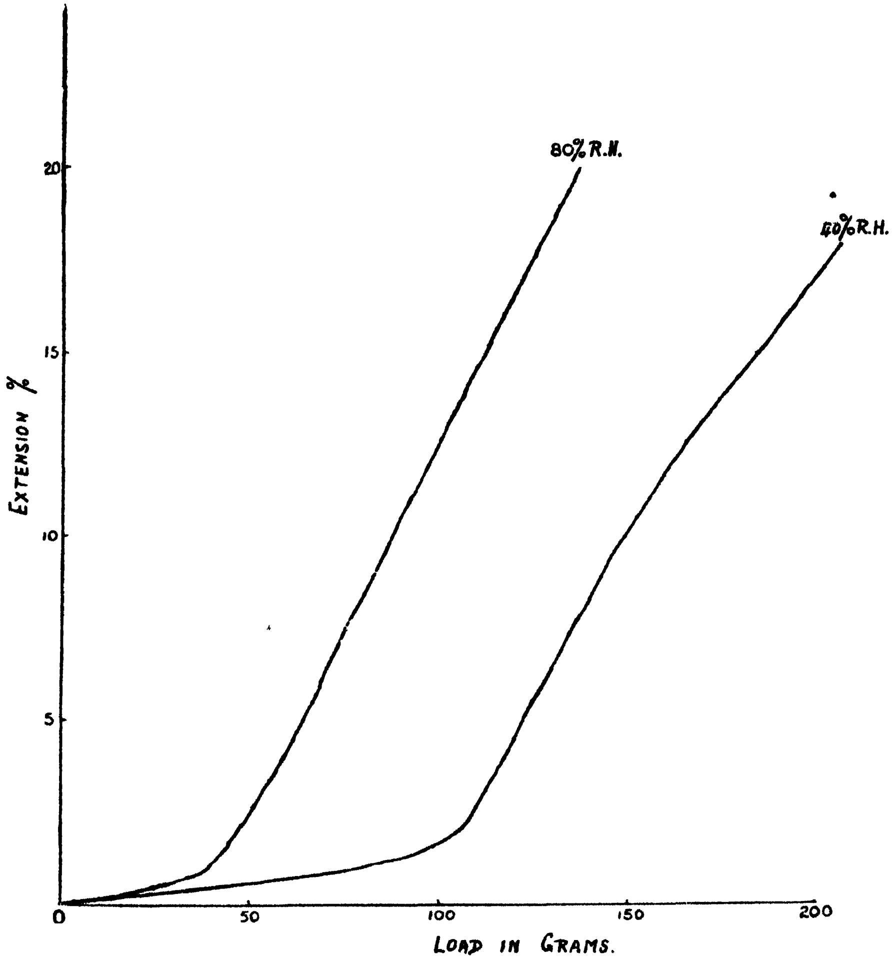

FIG. 2—100/24 Viscose

The absorption of moisture by any textile material alters the physical properties of the material to a greater or less degree. The following is a brief resumé of the effects of changes in relative humidity on the properties of rayon.

Breaking Load and Extension at Break

The higher the moisture content of rayon, the lower is the breaking load. The tenacity (breaking load expressed in gms. per denier) of viscose is about 1·8 gms. per denier at a normal humidity of 60% R.H. and this is reduced to 0·8 gms.

per denier when the yarn is thoroughly wetted. The corresponding figures for acetate yarn are 1·3 gms. per denier and 0·8 gms. per denier.

The change in extension at break with change in moisture content of the yarn is also very great. A viscose yarn with an extension of 20% at ordinary humidities (60% R.H.) shows an extension of 30% or more when broken after thorough wetting. Acetate yarns show a similar change in extensibility: 22% extension at 60% R.H. and 35% after wetting out.

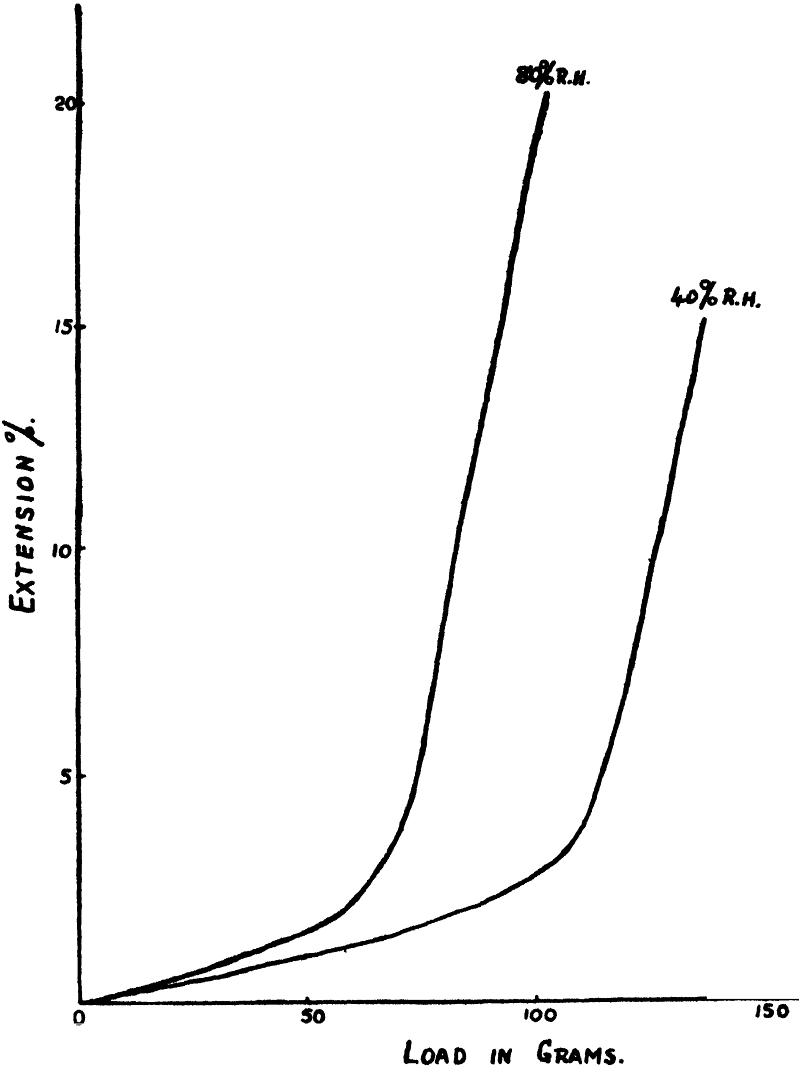

FIG. 2a—100/28 Seraceta

Stress-strain Relationships

From the point of view of the general handling of yarns in winding, warping, and weaving, the above figures for breaking load and extension at break are not directly applicable in so far as, in these processes, the yarns are never worked after thorough wetting-out and the stresses employed are not in the neighbourhood of the breaking load. A clearer insight into the changes brought about by changes in relative humidity can be obtained from stress-strain curves drawn at 40% R.H. (a common R.H. in winter) and at 80% R.H. (a not uncommon R.H. in summer).

Such curves (Figs. 2 and 2A) have been drawn for 100 denier 24 filament (100/24) viscose and for 100 denier 28 filament (100/28) acetate (Seraceta). The great importance of controlling relative humidity when applying tension to yarns can be seen from two observations made from an analysis of these curves.

(*a*) Whereas at 40% R.H. it takes a tension of 75 gms. to stretch 100/36 viscose 1%, at 80% R.H. only about 35 gms. are necessary. For 100/28 acetate, which is much less hygroscopic than viscose, the difference in tension is not so marked; the corresponding tensions are 46 gms. and 36 gms. respectively.

(*b*) The elastic limit at 40% R.H. for 100/36 viscose is reached when a tension of 90 gms. has been applied, but at 80% R.H. the elastic limit is reached with a tension of only 35 gms. As after that point, the extension increases very rapidly with increase in tension, the ease with which viscose yarns may be seriously strained at high humidities is manifest Again the differences in tension are not so great for acetate yarn; the elastic limit at 40% R.H. is reached by the application of a tension of 80 gms. and at 80% R.H. by a tension of 50 gms.

Swelling

As viscose absorbs moisture it swells both transversely and longitudinally. The maximum effect is obtained by thoroughly wetting the yarn and under these conditions the diameter increases by as much as 30% compared with the diameter at a normal humidity (60% R.H.) and the longitudinal extension is as much as 4%. The yarn returns to its original diameter and length when it is dried and reconditioned at 60% R.H. but this tendency for viscose yarn to lengthen merely by the absorption of moisture without the application of tension is an important point, especially when the viscose yarn is being processed along with another textile material.

The high extensibility of rayons at normal humidities, and the fact that this already high extensibility increases rapidly with increasing moisture content, render the yarns peculiarly liable to appreciable stretch by comparatively small tensions. When a yarn is thus stretched in processing, it is usually wound on to a bobbin or beam and given no opportunity to recover from the stretch, with the result that the first opportunity the yarn gets of dissipating the strain which has been set up, is in the grey cloth. As by this time the strain has probably been in the yarn for some time, the immediate recovery in the grey cloth will be small, as the power to recover diminishes with the length of time for which the stretch is maintained; but as soon as the fabric is wetted out, either in scouring, dyeing, or finishing, the strain in the yarn is released and considerable contraction may take place.

This increase in the recovery of a dry-stretched yarn by wetting it and allowing it to re-dry is particularly noticeable with viscose, as is shown by the following table, which gives the "dry recovery" and the "wet recovery" for a series of stretches. The tests were carried out on 100/24 viscose and the stretch was maintained for 2 minutes. In measuring the "wet recovery" the stretched yarn was wetted during the 2 minutes during which the stretch was maintained and the recovery measured after the yarn had re-dried loose.

Stretch in cms. given to one metre	Recovery in cms. "Dry recovery"	"Wet Recovery"
2	1·2	1·2
4	1·6	3·0
6	1·8	4·0
8	2·2	5·4
10	2·6	6·2
12	2·8	7·0
14	3·4	8·0

Fig. 3 shows the relative "wet recoveries" from various dry stretches of 100/24 viscose, 100/28 acetate (Seraceta), and 7/15 Canton silk (degummed). It will be seen that silk and viscose, especially at the smaller extensions, have similar powers of wet recovery and that Seraceta is considerably more plastic than the other two for extensions of more than about 3%. For smaller stretches it is more elastic; merely wetting the original unstretched yarn causes it to contract, removing the strains set up in the spinning.

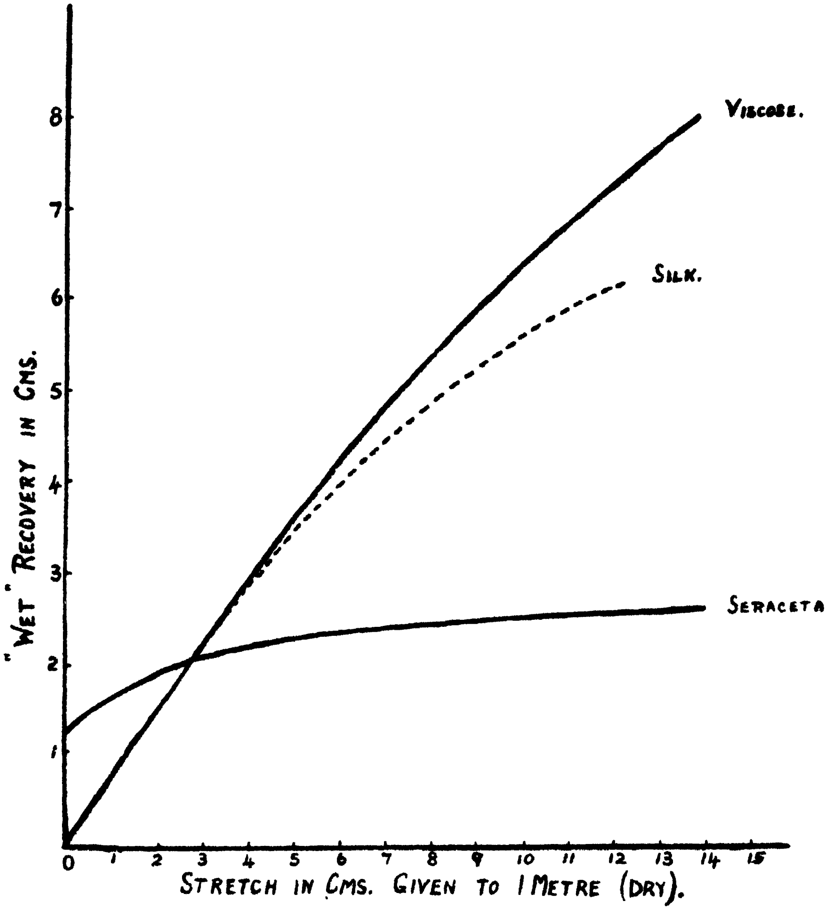

FIG. 3—100/24 Viscose; 100/28 Seraceta; and 7/15 Canton (Degummed)

The stretching of yarns due to the use of excessive tensions or of normal tensions at excessively high humidities, is most serious when the stretching is not uniform. If the stretch in the yarn is uniform, then the finished fabric will be uniform in appearance, although a piece in which the yarn has been stretched appreciably will have a slightly different appearance and handle than a piece in which the yarn received little or no stretch. But if the stretch in the yarn is not uniform, then contraction in the fabric will not be uniform and we have here an explanation of the obvious faults of bright picks, tight ends, etc.

PROCESSING

Since the finisher can rarely correct errors made in processing, it is extremely important that every stage should be done under the best conditions, on the most suitable machinery, and that the operatives should be well trained for their particular job. Further, as strained yarn may be produced by faulty manipulation of the yarn or running of the machines, an attempt is here made to describe some of the main processes and the precautions which should be observed to ensure the best results. Preconditioning and processing in an atmosphere of constant relative humidity is most desirable for winding, spooling, and warping, as the respective yarns are then reasonably equal in respect to their moisture content and will react alike to equal stresses involved in processing. A suitable atmosphere is one having about 60% relative humidity at a temperature between 68° to 73° F.

WINDING

The efficiency of subsequent processes being largely dependent on good or bad winding, the importance of good winding cannot be too strongly emphasised. The process of winding from skein to double-flanged bobbins is usually performed on a lightly constructed but rigid machine, double-sided like that usually employed for winding silk. The skein is first placed on the hands with the loose side outermost, it is then opened out gently on the back of the hands with the thumbs inside to avoid catching up the ends, and placed on a swift, again with the loose side outermost. At the same time the cross wires are pulled up to equal distances from the hub, opening up the skein to its full width. The side view of the skein on the swift should show an arrangement symmetrical about the hub, the swift will then be nicely balanced for even running; if unsymmetrical in arrangement it will run jerkily. The lacing knots should now all be lying on one side of the swift, and the lacings should be removed by cutting off the knots completely and pulling the lacings through from the side opposite to these knots, thus avoiding any displacement of the yarn in the skein or catching up and disturbing the crossings, which might arise if the knots were pulled through the skein.

It cannot be too greatly stressed that a little extra care taken in placing the skein on the swift in an even and open manner will repay in better running or greater production, as well as preventing "hold-ups" and end breakages. Any check to the rotation of the swift may cause sudden increases in tension amounting to several hundred per cent. of the normal tension, the effect increasing as the rate of winding is increased.

Broken ends should be found without seriously disturbing the lie of the yarn on its swift, and, at the same time, if necessary, the cross wires are again pulled up into symmetrical positions to give even running.

On some machines the swifts are placed below the winding bobbin, the yarn is then run from under the swift; in other machines the swifts are placed above the winding bobbin and the yarn is run from above the swift.

The tension required in running should be sufficient to produce a moderately hard bobbin and is usually derived from a weight hanging on a strap round the hub of the swift; about 6 to 8 ozs. is usually sufficient for this purpose.

In the simplest type of winding machine, the bobbins are driven by either single or double friction bowls, about 1½ in. in diameter, which receive their motion from a flat-faced pulley of about 5 in. diameter and ½ in. face, fixed on the main shaft which runs down each side of the machine. The friction drive being a light one, any obstruction to the free running of the swift usually holds the bobbin without seriously straining the yarn, provided it is dry and the winding is in a dry atmosphere. The average winding speed of the main shaft should be about 150 r.p.m. for undyed yarns; this gives a winding speed of from 200 to 400 ft. per minute, depending upon the diameter of the winding bobbin. Coloured yarns are wound at a slower speed, the shaft running at 90 r.p.m. It is extremely important that hank-dyed yarns should be wound at lower speeds, as hank-dyeing tends to make yarn less windable the longer the period in dyeing, and experience has shown that proper drying and conditioning has considerable effect upon the windability of such yarns.

The yarn from the swift usually runs over a porcelain guide fixed on the traverse rod which lies close to the winding bobbin. The traverse is usually designed so that the guides move over a distance about ⅛ in. less than the width between the flanges of the winding bobbin. It is actuated by a double cam which makes the traverse rod hunt ⅛ in. If the guide to each bobbin is properly set this ensures a well-shaped bobbin being wound, and one which will run off freely at the ends of the traverse during unwinding. It is essential that the porcelain guides should be perfectly smooth and uncracked in order to prevent damage to the yarn.

Bobbins used for warping may contain up to 8 oz. of yarn according to the denier which is being wound, but it is customary to use smaller bobbins containing only about 2½ to 3 oz. for spooling.

The above comments on manipulation apply equally to the spindleless type of winding machines. These machines are frequently run at higher speeds and rely upon automatic stopping devices to prevent straining due to entanglements; should these devices fail to act, the yarn either breaks or the machine plucks the entanglements free and winds strained yarn.

The normal tensions in practice during the course of winding on the silk type of winding frames are only small, rarely exceeding 25 grams or about 1 oz., and are insufficient to strain the yarn under normal conditions of moisture content and relative humidity; but if viscose yarn is wound damp it is likely to be strained either in this or in subsequent processing. Yarn which is wound damp will most probably remain damp at the next stage in processing as yarn on bobbins takes much longer to condition than yarn in hank. Hence the advantage of winding under perfect humidity control.

WARPING

In the early days of rayon manufacture, apart from knitting, the yarn was largely used for weft only and not for warp, but with improvements in quality and experience in processing it came largely into use as warp also, and to-day many beautiful all-rayon fabrics are woven, or rayon warps are employed with filling of either real silk, cotton, or wool.

The horizontal section warping mill, similar in principle to that employed in the silk industry, is the best machine for rayon. The choice of creel depends on the type of work and its volume. For large scale production, warping over-end from cones is preferable, but for general purposes the vertical V-shaped creel is suitable.

For warping from the latter, the yarn is first carefully wound on double-ended flanged bobbins, with uniform tension to ensure that all the bobbins are equally firm and contain about the same length of yarn. An extra hard bobbin is likely to contain stretched yarn which is carried into the warp and produces stripiness in the finished fabric. The creels contain from 400 to 600 bobbins, so arranged that yarn from the bobbins runs to the leasing reed without bending through any sharper angles at the reed than necessary, yet so arranged as to give the warper a clear view of each end to facilitate the early detection of breaks. The yarn is entered into a leasing reed from under a guide rod, passing through a second reed and under a wooden guide roller to the reel. The rate and denting of the second reed depends on the number of ends per inch required in the fabric. Leasing rods are used to maintain the sheet of yarn in a "split" condition as it passes through the second reed. In the case of acetate warps, it is preferable to have a third reed placed after the wood roller and as near the mill as possible. This is intended to prevent flowing due to electrification. The reeds and rods should be clean and free from any rough or rusty places, which would be likely to cause breakage of filaments or chafing of the yarn.

The yarn is drawn on to a horizontal section warping mill off the sides of the bobbins, and as far as possible the bobbins should all contain approximately the same length and weight of yarn so as to avoid uneven tensions between the ends, due to pulling round bobbins of unequal weight. Such uneven tensions will produce twilling in a satin and stripiness in other warps. A vertical column of nearly empty bobbins, used with a set of full bobbins to make up a warp, may give rise to stripes seen at intervals across the finished fabric in warp runs.

The warp is built in sections on the horizontal mill. The first section is built up on a set of shoes on the side of the mill by a slow traverse motion of the carriage as the mill is rotated The angle at which the shoes are set is determined by the traverse, the denier of the warp, and its rate; if the angle is too small the warp tends to be tight near the selvedges when it gets on to the beam, on the other hand with too large an angle it is slack near the selvedges on the beam. Regarding selvedges, it is a matter of opinion whether these are run on the first and last sections of the warp, or whether the selvedges are warped separate on small selvedge bobbins

The speed of warping is usually about 70 or 80 yards per minute from the vertical type of creel A more modern system, which has been adopted on a large scale in the United States during the last year or two, and is now finding favour in Germany, is the high-speed machine warping from creels holding large cones containing some 2 lb. of yarn. The latest of these machines are fitted with creels of the magazine type in which the change from the empty to the full cone is made without stopping. Such creels must be fitted with suitable tensioning for each end, and with automatic electric stop motions which stop the machines immediately a break occurs. These machines run at three to four times the normal speed and it will be readily seen that they are only of advantage where a large number of similar warps is required.

Where yarn is warped from bobbins mounted on spindles on the creel and the bobbins are rotated by the pull of the yarn in warping, it is important that the spindles should be straight and properly aligned. The spindle holes in the bobbins should not be badly worn, and the washers on which the bobbins rest should all be as equal as possible.

Any unevenness in tension as between end and end or any chafing which continues throughout the warping, may be expected to appear in the finished fabric as stripes in the form of warp runs.

Acetate yarns are particularly liable in dry weather to produce static electrification during all stages of dry processing and the effect is particularly noticed during warping and on the weaver's beam at the sizing machine. The greatest effect is seen at the join of the warp runs. Electrification of the yarn causes the ends to repel each other and the effect is mainly seen at the edges of each section being warped, where the ends have a tendency to flow outwards. This makes it difficult for the warper to locate the true edge of the run.

The effect may be counteracted by the use of static eliminators or reduced by the use of suitable damping devices, but the latter must on no account be used with viscose yarns, these latter are not prone to the production of static electrification but, as aforesaid, are very susceptible to moisture.

It is common practice to insert an end-and-end lease at the beginning and end of each warp.

In beaming it is essential that the flanges be set to the exact width of the warp as measured on the warping mill. A warp for sizing should not be wound too hard but should be wound so as to run off regularly without displacement during beam sizing. As the beam is positively driven in warping, the speed of the yarn increases as the diameter of the beam increases and some beaming machines are fitted with gearing to reduce the speed of rotation of the beam as the diameter increases, which proves useful on very long warps. It is good practice to cover the beam with a layer of paper or card immediately after the warp has been attached to overcome any irregularities in the beam surface.

SIZING

Sizing on beam of rayon warps in this country is usually done on machines with cylindrical dryers. Viscose yarns are generally sized through a pair of squeeze rollers and do not require immersion with most aqueous sizes as viscose yarn wets-out readily; on the other hand acetate yarn does not wet-out readily and requires immersion in the sizing mixture.

Close co-operation is necessary between the weaver and the warp processor owing to different weaves presenting their own problems of sizing. For example, taffetas require a soft size, and heavy corset cloths require a hard size. Constant research is proceeding on new ingredients, viscosities, and temperature to ensure a coating of size which will stand up to loom friction and will, at the same time, give easy scouring.

Since viscose and acetate yarns tend to stretch slightly when wetted by the sizing mixture, rigid supervision is required of the speeds and adjustment of the different cylinders, rollers, and take-up.

The beam flanges are generally set slightly narrower than the warper's beam and the yarn is run on at such a tension as to give a uniformly hard beam.

Some acetate warps have a tendency to tape during sizing and may build up badly on the weaver's beam unless paper or card is inserted there at intervals. The speed of sizing is largely controlled by the drying conditions which should not be too severe.

Viscose yarn wets out more readily than acetate does, while the former when saturated contains nearly 100% of water the latter only absorbs about 30%. It thus becomes important in aqueous sizing to pass acetate yarns through a more concentrated size to obtain a similar degree of sizing.

PIRNING

Direct pirning from skeins is definitely not satisfactory for singles rayon yarns and it is usual first to wind the yarn on to spooling bobbins. Pirning is a process which is singularly liable to produce defective yarn. As there are many moving parts on the machines to get out of order, the running conditions require careful watching. The mean tensions employed during pirning are much greater than those found in the winding process, therefore, the condition of the yarn in relation to its moisture content and the relative humidity of the atmosphere during pirning is an important factor. Hence viscose spooling, in the best practice, is always performed in a conditioned atmosphere of about 60% R.H. and about 68° F., the yarn being first adequately conditioned in hank before winding and wound in a similarly conditioned atmosphere. It is particularly in the summer time, when high relative humidities prevail, that viscose yarn is liable to produce "shiners" from being strained in spooling. While straining cannot be produced without undue tension, the prime cause is often the damp condition of the yarn, either at the time of winding or pirning. In our own factories all our yarn is wound under perfectly controlled.atmospheres.

Apart from allowing the yarn sufficient time to condition before pirning and processing in a conditioned atmosphere, the following points of adjustments on the machine need attention and certain other running conditions should be observed. While the machine should be properly lubricated, over-lubrication should be strictly avoided on all external parts. The machine should be kept clean and particularly free from dirt, fluff, or yarn on the spindles of moving parts, such as the runners or builder motions. The compensator springs should be properly adjusted and set so that they are approximately horizontal in their main working positions. When allowed to take too high or too low a mean position, the working of the compensator is less effective. The fibre guide pulleys should be examined to see that they are free on their spindles and that grooves or ridges have not been cut in them by the running of the yarn. Undesulphurised yarns tend to cut the pulleys, as also does real silk to some extent, and such damaged pulleys should be discarded. All porcelain guides or parts over which the yarn runs should be examined to see that they are free from roughness, while the builder motion should be similarly free and make but light contact with the yarn. Spindles should be straight and running true, while the stop motions should be functioning either when the pirn is full or when a thread breaks. Brake tensions should be equalised from spindle to spindle.

The feeding bobbin should be firmly wound and properly traversed so as to give free running, particularly from the ends of the traverse, while the inside of the bobbin flanges should be free from damage. The yarn should move freely over the runner on the compensator spring, and care should be taken that the yarn has not slipped over this runner on to its spindle wire, as in such cases yarn is bound to be strained and tight picks ensue. All knots made during pirning should be laid at the back of the traverse outside the winding so that the yarn runs off freely. For high-class work knotless yarn may be employed.

Owing to the slippery nature of rayon yarn, it is liable to slough off the nose of the tube through the repeated shocks which it sustains in weaving. This may be obviated by adequate pirning tension, by layer locking or differential winding, by the indented rings on the surface of the pirns and by the suitable angle of the chase.

Pirns should be made of either paper tubes or well-seasoned varnished wood, capped at the end with brass ferrules. The latter type are not so suitable for transporting. Paper tubes should be sorted each time before refilling and all dented tubes should be rejected. Some tubes are designed for bigger differences between the circumference of the nose and the base of the chase than others, in some cases the difference amounts to 100%. This is rather large and a smaller ratio is desirable, as the larger the difference the greater the variation in pirning tension and the greater the demand upon the compensator. The speed of the spindles should probably not exceed 1,700 r.p.m. with conditioned yarn, and less if unconditioned, in order to ensure that all the product is unstrained. At this speed the yarn is being wound at a velocity of from 200 to 400 feet per minute depending upon the diameter of the pirn at the nose and the base of the traverse.

The mean tension during pirning is mainly determined by the load on the brake drum and the coefficient of friction between the drum and brake band. There is a progressive increase in the mean tension as the feed bobbin empties. There are also periodic variations in tension, repeating every pirn traverse and due to variations in yarn demand from the nose to the base of the traverse. Further, there may be quite excessive variations super-imposed on the two former types of variation due to the "start-up" effect accompanied by inadequate compensation or produced by faulty and irregular feed bobbins.

While the mean tension during pirning may be anything from 25 to 50 grams (say, 1 to nearly 2 oz.), the variation due to the bobbin diameter decreasing may increase this by as much as 100% and the variation due to a "starting-up" effect may increase the mean tension by several hundred per cent., depending upon the acceleration of the spindle. Any such high tensions almost invariably produce "shiners" in viscose wefts and are not unknown with both acetate yarns and real silk.

A number of devices have been invented for reducing excessive tensions in pirning due to any cause whatsoever. Their action mainly depends upon some mechanism for moving or reducing the braking force acting on the brake drum whenever the tension exceeds some critical amount. Such devices as have been examined have so many points of adjustment that it is extremely difficult to obtain a critical setting on a single spindle, while they all rely on an already existing variation in tension to bring them into action and some strain may have been produced before they function.

Pirning then is clearly an operation which requires the most careful consideration in the perfection of the machinery employed and in the control of the conditions in running.

The common defect of strained yarn produced in pirning takes the form of tight picks or "shiners", strained weft often seen in the grey fabric on the loom, cockling of shoot, and weft bars of uneven contraction. In piece-dyed goods the full effect of strained yarn is not seen until the fabric is stentered out to its finished width; this is due to the high recovery power of strained viscose yarn when it is wetted out, as explained in the earlier part of this paper. The intensity of weft "shiners" is obviously affected by the finished width of the fabric, the greater the finished width, the more obvious they generally appear.

Tight picks often occur in definite patterns due to a periodicity of incidence of the cause in pirning, the period often being that of the complete traverse length on the pirn. This was dealt with in a paper by H. Hegan and A. B. Shearer in the *Silk Journal* for 1927, 3, No. 32, 67. It has since been found that the period is sometimes a multiple of the traverse length and tensions have been measured in starting up machines where the peaks occur at 2, 3, 4, 5, or 6 times a traverse length.

Cockled and strained places may often occur in taffetas containing viscose shoot, which has been hank dyed, and where the fabrics only receive a loom finish. Strained yarn will often show up in the loom with such a class of goods, but the worst defect only develops later after the fabric has been exposed to a damp atmosphere; the viscose then starts to recover and cockling ensues.

WEAVING

Rayon yarns are much more uniform in denier and appearance than any staple yarns, and therefore the weaving conditions require to be more perfect as there is no tendency for yarn irregularities to cover up weaving defects. Rayon fabrics have generally a more sheer appearance than those made from cotton or wool and small defects appear rather distinctly. As rayon yarn is a continuous filament yarn any chafing, bruising or breakage of filaments also appear to disadvantage, whereas similar treatments scarcely affect the appearance of a cotton or wool fabric.

Rayon can be woven successfully in looms of either silk or cotton type providing the necessary modifications are made and precautions taken. The most important general precaution is the elimination of all causes of unnecessary friction between the warp or the weft and the loom.

In order to avoid the common pitfalls in weaving rayon yarns, it would be well to first consider the parts of the loom associated with its three primary movements of shedding, picking, and "beating-up", and their respective adjustments.

Shedding

Wire healds are preferred to cotton healds. They should be selected with wires as fine as strength permits and as smooth as possible, while the mail eyes should be equally smooth and as small as reasonable. They should always be carefully examined and rejected for imperfections. Any excessive friction in the eyes, or along the wires due to roughness, or any shoulders on the mail eyes, will produce a form of stripy warp and probably cut filaments or cut ends, which may cause floats or wrong lifts. Heald wires should be capable of a lateral and free movement on the shafts, which enables them to take up a correct alignment with the warp in relation to the run of the ends from the weaver's beam to the reed. Bent wires, or the congestion of wires against the supporting hooks, will cause either friction marking or alter the tension on the ends, resulting in a different lie of these ends in the cloth, producing an optical effect on the warp which is never removed in finishing. This applies equally to any uncorrected displacements made by the weaver in the course of taking in broken ends. By virtue of the great uniformity of rayon yarns, such optical effects produced by tension or other causes often appear very distinctly although the cause is only slight.

Where trouble is being experienced due to the above causes, it has often been found advantageous to provide lubricating rods to the warp as it comes from the beam. This often successfully reduces milky stripes due to these causes, although it is preferable to eliminate the real cause.

While knitted healds can always be recommended for maintaining a constant alignment of the warp ends, they are not commonly applied on account of their cost, and because of the large stocks which would be required.

Slating or rolling the healds can be resorted to where knots are causing trouble or where the warp has a low margin of strength, and this should have a good effect on the weaving in the case of a plain weave on six or eight shafts, as it eases the crossing, reducing crowding and friction.

The shed for rayon warps should not be large but sufficient to allow the shuttle to pass without detriment to the warp. A smaller shuttle is recommended than that generally employed with cotton or wool, but is not essential. A good length for the shed between the healds and the back beam is desirable as it reduces the strain on the yarn in shedding

Picking

Picking should be adequate to carry the shuttle properly home, but not harsh enough to cause sloughing of the yarn from the pirn. The shuttle checking should be as smooth as possible and the use of double swells has proved efficient in working.

The sley must be perfectly true, the batten and shuttle boxes truly aligned and levelled up with each other, or shuttle marking will occur, or ends be broken. The batten is covered with swansdown or suitable cotton cloth or plush glued down to the full length of the race board. This acts as a cushion into which the warp ends tend to bend down and so reduces shuttle friction on the warp itself to a minimum. Care should be taken when covering the race board that glue does not flow over the side and be left there to form a blob and displace the dents of the reed.

The shuttles themselves should be well made in hard wood and kept polished with the smallest amount of linseed oil. All sharp or rough places should be removed. Shuttles should be frequently examined to see that they are kept in the smoothest possible condition and the metal tips should be perfectly smooth and flush with the wood. They should have a large porcelain eye which is suitably "brushed" with a soft twisted worsted or mohair yarn, and suitably "furred" inside. The degree of brushing and furring is a matter of experience, being largely determined by the tension required in weaving and by the particular type of weft.

Furring is intended to control the weft on the pirn and prevent slippage of the coils previous to the demand of the picking. The fur is generally glued to the inside of the shuttle, and if any glue is left on the furring or inside the shuttle, it may cause trouble; quite a small amount may cause obstruction to the free running of the weft, setting up tension and causing strained places, tight picks, and weft bars.

For weaving "double shuttle" fabrics the shuttles should be identical and equally tensioned.

"Beat-up"

Reeds should be carefully selected, the dents should be flexible and as fine as possible to give the maximum room for the yarn. Any increase in the strength of the dents should be obtained by increasing their depth from front to back. Flexibility of the reed is important with rayon, as it assists the passage of knots; greater flexibility can be obtained by employing a reed with greater depth. Their edges should be rounded and specially polished to reduce friction with yarn to a minimum. They should be kept perfectly clean, and it is good practice to always clean the reed before entering a warp and after each warp is woven out.

General Running Conditions

There should be no unnecessary play in any of the moving parts of the loom and no loose or worn bearings. It is a good plan to run the loom without the warp or shafts, in order to study the flight of the shuttle, adjust the strength of picking and check, and to assist the overlooker in making any preliminary re-alignments or readjustments before entering the warp.

Attention should be given to shuttle boxes and pickers. They should be free from all roughness or projections and, as a precaution against damage to the weft, the inside of the single box in contact with the weft should be lined with a strip of swansdown suitably fixed for easy replacement. This avoids damage to the weft, preventing such defects as box marking and chafed or cut shoot.

The nose of the shuttle itself may be wiped with a rag containing a trace of mineral oil, as this tends to reduce friction with the warp and may have an effect of reducing any liability to shuttle marking.

Warp Adjustments

Various methods are employed in tensioning the beam; generally the ordinary rope let-off is employed, but oscillating tensions are sometimes used for more delicate warps. In all cases the ruffles on the beams should be reasonably smooth, large, and true, and kept in good condition. It has been found in lengthy practice that fine graphite is the best dressing for manilla ropes. Any dressing which is subject to variations in its frictional properties due to changes in temperature or humidity should be avoided. Heavily-glued ropes are particularly bad.

The weaving tension required is dependent on the type of warp and fabric being woven, and its adjustment is a matter of experience for the overlooker.

Back rests should be horizontal and adjusted in height according to the requirements of the fabric being woven. The revolving back roller is kinder to the warp than the fixed back rest, and is to be recommended for weaving rayon. It is made of either steel or a very hard wood on a steel spindle mounted on ball bearings. All back rests should be sufficiently strong to avoid sagging. On some looms the warp beam is readily adjustable and can be kept up to the level required, either by hand or automatically, as the diameter of the weaver's beam decreases; in such cases there is no need to use a back rest.

Lease rods create a large amount of friction on the warp and it is preferable to avoid their use with rayon warps. This can be done by employing a false heald between the healds and the back rest. The false heald remains stationary in loom and, as a certain number of warp ends are entered between each heald wire at the time of drawing into the other healds, it helps to keep the warp ends in their relative positions so that the weaver can find the correct position for entering a broken end.

The reed must obviously be adjusted in lateral position so that when the warp has settled down to weaving the line of warp ends is undiverted.

The Take-up Roller

This should be covered with a suitable material which prevents slippage, or thick places will be produced. Rubber or fine-grade emery are the most suitable, and in either case care must be taken in the preparation of the surface. This must be done carefully to avoid any unevenness in surface or diameter, which would tend to crease the fabric.

Timing

The timing of shedding and picking in relation to beat up for rayon warps follows the practice in silk weaving, and is different from that which obtains in cotton weaving. The healds are level at the beat up with rayon warps, so as to avoid beating up on an opening shed and putting unnecessary strain on the warp. It is also kinder to the weft. The picking comes into operation slightly before the shed is fully open, thus ensuring that the shuttle is in the opposite box before the shed closes.

Temples

For many rayon fabrics temples are unnecessary, but where they must be employed the most suitable form is the ring-pin temple which acts on the selvedge alone.

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APPENDIX

A collection of fabric faults has been made to illustrate the effects of faulty processing or weaving; these have been selected from actual production. They will be on exhibit at the Annual Conference and they illustrate the following defects—

Defects associated with warp are labelled with a capital "A", and those associated with weft with a capital "B".

A.1: *Tight Ends.*—
  (*a*) Due to high relative humidity and moisture content and/or high tension.
  (*b*) Due to knots.
  (*c*) Due to uneven tension in hank-sized warp.
  (*d*) In voiles.

A.2: *Slack Ends*—Due to low tension.

A.3: *Reppiness*—
  (*a*) Due to unsuitable sizing.
  (*b*) Due to standing places.

A.4: *Reediness.*

A.5: *Twilling in Satin Weaves*—Due to unsuitable denting.

A.6: *Chafing in Loom.*

A.7: *Warp Streaks*—Due to displacement of warp.

B.1: *Tight Picks*—
  (*a*) Incident in pattern form.
  (*b*) Strained places
  (*c*) Cockled places.

B.2: *Box Marking.*

A further group of fabrics will be exhibited showing defects associated with the processing of viscose rayon under unsuitable conditions.

The effect of using partially damp yarn in the following forms—

C 1: in skein form.
C.2: in bobbin form.
C.3: in pirn form.

The effect of conditioning in a high humidity—

C 4: in skein.
C.5: on bobbin.
C.6: on pirn.

The effects of further faulty conditions—

C.7: in pirning, *e.g.* starting-up effects, abnormal tensions, knots, etc.
C.8: in weaving, *e.g.* faulty furring, brushing, etc.

In order to illustrate the type of pattern marking which would be seen in a finished fabric from using yarn which is damp in various parts of a skein (C.1), a bobbin (C.2), or a pirn (C.3), yarn has been damped by means of an aqueous stain and the corresponding grey fabrics are also shown. It is obvious that the type of pattern formed will depend upon the distances apart of the damp places in the skein or on the bobbin or pirn, and the reed width of the fabric.

SOME OBSERVATIONS ON FABRIC STRENGTH IN RELATION TO YARN PROPERTIES AND DENSITY OF STRUCTURE

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It has long been known that the interlacement of one set of threads with another leads to an augmentation of the resistance of both to breakdown under load. Among other pioneers in the field of textile research Myers[1] may be mentioned as having experimented in that connection, and it seems from his publications in 1911 and 1914 that he saw the desirability of making an exhaustive investigation of the problem. In these early stages, however, the real position was somewhat obscured owing to a wrong basis of comparison. Apparent losses in strength due to cloth formation, sometimes large losses, were found, and these were either left unexplained or, in the case of warp-way tests, explained on the assumption that the yarns had been damaged by the stresses of weaving. This arose through comparing fabric strength with single thread strength, and overlooking the fact that the breaking load of a group of threads is not the same as the sum of the strengths of the individuals. It is true that Oliver[2] in 1907 published a paper in which reference is made to the behaviour of composite specimens, but it was not, I believe, until Turner[3] had drawn attention to this consideration in 1920 that its importance was generally recognised from the point of view of experiments in fabric structure. What may be regarded as the finishing touch was provided by Peirce[4] in his paper on "The Weakest Link" published in 1926.

Unfortunately, the relation between group-strength and single-thread-strength varies from yarn to yarn depending on the degree of irregularity, and although the former may be derived from the latter, the calculation is not easy and requires a considerable volume of data on which to work. For experimental purposes, therefore, it is simpler, and on the whole more satisfactory to use as a basis of fabric strength the strength of a group of threads tested as such. In the case of warp yarn the preparation of the test specimen is easy. All that is required is a seven-inch length of unwoven warp with a four-inch strip of closely woven fabric at each end, the whole of which can then be divided up into a number of test pieces containing the desired number of threads. In the case of weft, however, it is necessary to wrap the desired number of threads on a wrap-reel using a straight traverse and a constant tension; and to use wide adhesive plaster in lieu of fabric for clamping between the jaws of the testing machine.

The way in which this grouped thread "basis" is strengthened by cloth formation has already been extensively discussed by Turner and others, but it is felt that the subject will bear yet further examination and elucidation. It is not sufficient to know that the operation of this or that factor contributes to the results observed. Only when we have learned more of the *magnitude* of the effect, in relation to the various structural constants of both yarn and cloth, will we be able to provide the fabric designer with straightforward and practical solutions to many of his problems. The main difficulty lies in the isolation of the various factors concerned and the accurate estimation of their separate effects under different conditions.

One of the more important factors that call for consideration in this respect is that of yarn twist. Corser and Turner[6] have already made a contribution to the subject so far as folded yarns are concerned, and have indicated how the interlacement of warp and weft can supplement the effects of yarn twist in reducing loss of strength by fibre slippage. On the other hand little or no definite information is as yet available as to the behaviour of variously twisted singles yarns on cloth formation; nor as to their reactions to the different structural features of the cloth such as, for example, the set of warp and weft in relation to count, and the degree of corrugation of the component yarns. It is to be noted that, as in the case of yarn alone, the inter-fibre pressure that yarn interlacement can provide exists only when the cloth is in tension*; so that the fibre slip issue is likely to be complicated by other changes that accompany changes in twist—notably in the way the yarn can be flattened, compressed, or otherwise deformed while under test. The problem is, therefore, not a simple one, but the potential practical value of conducting an extended investigation along these lines is beyond question, more especially in view of possible developments in the use of twistless weft.

Another aspect of cloth construction from the point of view of strength is the way in which the area of breakdown is restricted as the density of the weave increases. In unwoven strips of warp for example, the rupture of the individual threads takes place, according to the location of the weak places, anywhere between the two jaws of the testing machine. The weakest places stretch more than do the other parts of each strand, and so arrive first at the breaking point. Thus at any point in the sample the chances are that there will be a small, but none the less important, relative movement between adjacent threads. When weft is present, however, such relative movement is restricted to a greater or lesser extent, and there is a tendency for excessive stretching in any part of one thread to be prevented by a lower rate of stretching in the adjacent threads to which it is more or less effectively bound by the weft. These in turn are influenced by others still further removed from the vulnerable point; so that each weak place makes demands for assistance on a number of threads on either side of it. The denser the structure, the less the freedom of movement as between adjacent threads, and the greater the reinforcement given to the weak places. Hence there is an increased delay in breakdown and a consequent increase in fabric strength. However, it is not merely a question of the ***number*** of threads that are called up as reinforcements, but also a question of their ***quality***; for, of any two weak places in a specimen, it is quite possible for the stronger one to break down first, simply because of the poorer quality of the support rendered by its neighbours. In so far as the importance of the very weak places is thereby diminished, we have here a situation analogous to that in which the apparent single-thread-strength is increased as the length of test specimen is decreased. The increase of strength due to structure is, therefore, likely to vary according to the degree of regularity of the yarns employed. Furthermore, in the denser structures at least, it may very well be that the range of cloth strengths will be found to be appreciably less than the range of strength of the yarns from which they are made. It may even be found that the benefit to be derived from using two-fold yarns because of their greater uniformity will be so small as to make it worth while using more carefully-made single yarns instead.

We have, then, in yarn twist and yarn regularity, two of the major factors that must be reckoned with in cloth construction. It need scarcely be added that there are others; but for the present these will suffice, having in mind the short time available for discussion. There is one aspect of the problem, however, to which very little attention has so far been given, and which might well be ventilated here.

It is a matter of universal agreement that, because of the number of intersections it provides, the plain calico weave is capable of producing stronger cloth than any other. Also, it has been found by experience that generally the best results are obtained with a closely-woven fabric. But there are not many who have considered the question of whether density of structure may be carried too far; whether, in fact, by increasing the density of structure beyond a certain point the cloth strength may be even seriously impaired.

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* Theoretically, and may be in fact, it is possible for the component threads to be in tension, even though the cloth as a whole is not; but this will apply only to fabrics of very dense structure. Generally, the contraction of the cloth in length and width after leaving the loom is sufficient to reduce the initial yarn tensions to very small proportions.

In a number of experiments carried out by groups of students in my department during the last few years, optimum values of structural density have been found which it is proposed to investigate in greater detail. In each case the experiment involved measuring the warp-way strength of a series of fabrics having a common warp but having picks per inch ranging from zero up to the maximum that could be inserted without throwing an excessive strain on the warp. The following figures for warp way strengths as found in three of the experiments will serve to show the kind of results obtained—

I—Warp 2/52's. Weft 30's. Ends per inch in reed 72.

Picks per inch	0	32	53	72	85
B.L. per 2 inch width	156	166	176	160	119

II—Warp 2/36's. Weft 30's. Ends per inch in reed 72.

Picks per inch	0	30	50	70	78
B.L. per 2 inch width	172	180	196	210	203

III—Warp 20's. Weft 20's. Ends per inch in reed 56.

Picks per inch	0	40	56	70	76
B.L. per 2 inch width	63	76	84	91	81

In seeking for an explanation for the final fall in strength one naturally thinks first of the angle which the yarn makes with the plane of the cloth at every intersection, on the ground that the greater the angle, the lower the force that the yarn can transmit in that plane. Turner[6] raised this point in his discussion of the cloth strength test, and considered that its effect would be small, though at the time of writing he may not have had in mind the very highly-picked cloths with which we are now dealing. Where both warp and weft are tightly packed the warp cannot straighten itself out very much when under test, and the yarn-cloth angle at each intersection must remain at a fairly high value right up to the instant of break. This factor, therefore, undoubtedly plays a part, though from general considerations it does not seem likely to be responsible for a loss in strength of more than about 20%. How then are we to account for the 31% loss observed in experiment I? For the yarn inclination to be solely responsible, the angle at the instant of break would have to be 45°, which is almost incredible. If we could only measure the angle, we might be able to settle the question, but the possibility of ever being able to do this is almost equally incredible.

The next point one might think of, is the possibility of the warp threads having been greatly weakened by the forcing of the picks into place. Measurement of the strength of the threads withdrawn from the cloth, however, shows that this is not the case. A slight weakening is observed, it is true; but not nearly great enough to account for the loss in cloth strength.

Finally, perhaps, we may ask ourselves whether the observed fall in strength is after all a real fall, and not merely a consequence of the way the cloth strength is tested. It is due to the exposition of Turner (*ibid*) that this doubt arises. In his discussion of the behaviour of cloth specimens he points out that, owing to the unequal removal of the yarn corrugations during a test, premature rupture must be expected with closely woven fabrics. Yet again one may ask whether the concentration of stress which he thereby envisages could be sufficient to account for the losses observed. The most obvious symptom of this concentration of stress is the formation of a "waist", and it may be that measurement of the "waist" can provide a clue as to the reality of the phenomenon. Tentative experiment in this direction has already been made with results that are in favour of reality. Thus, for example, in Experiment III, the width of the waist at break was found to be 1·65 inches for the 56-pick cloth and 1·72 inches for the 70-pick cloth. The fact that the latter gave the higher value may be put down to the greater closing up of the ends on desizing, the ends-per-inch in the two cases being 61 and 64 respectively.

Thus in this case at least, the increase of picks does not seem to have led to any increase in the narrowness of the waist.

It is important to note that this, what may be christened the "Turner Effect", is expected to operate mainly in the case of closely-woven fabrics among which the strongest structures are to be found. A great deal of importance must, therefore, be attached to any future work which will throw further light on the extent to which it may be discounted in the ordinary fabric test.

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THE STRUCTURE OF MODERN FABRICS

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Woven fabrics supply one of the fundamental necessities of mankind. They are available in enormous variety and it would appear to be an impossible task to create something really new in woven texture. In fact, it is only when we extend our range of observations over a fairly long period of time that we become conscious of new developments.

The expression, "modern fabrics", must of necessity include the developments which have taken place in recent years. For example, an entirely new fibre element was introduced some twenty years ago by the production of rayon, and the application of this yarn in woven fabrics has passed through many phases during the past two decades. To-day rayon yarns have a predominating influence in many branches of fabric structure, especially in dress goods of the lighter types, and in many classes of soft furnishings. Rayon was originally considered of value because of the high lustre it imparted to a fabric, but now it is available in any degree of lustre, from a dull matt effect to the original brilliant examples, and also with different degrees of twist inserted, and with crêpe or non-crêping properties. We also find many of the old fundament weaves are used in conjunction with new yarn elements and new methods of finishing, so that modern fabrics have their foundation in the past, but are subject to different modifications to suit prevailing taste or fashion.

Progress in fabric structure consists very largely in the expansion or modification of methods and results already well established, that is in the sense of having found a ready market. The changes which take place are in the main evolutionary in nature, and are based upon experience in manufacture and behaviour under every-day conditions of service. Apart from fabrics intended for industrial purposes, such as tyre-fabrics, hose pipes, typewriter ribbons, interlinings, and similar goods, the products of the weaver's art are subject to the judgment of the consumer's eye and sense of touch in the final selection. This is especially the case in fabrics intended for clothing and general domestic use. It is this selection on the part of the consumer which determines whether a fabric is fashionable or out of date. Science can do very little in directing judgment which is distinctly empirical in nature, and so long as we have a discriminating public, it is futile to speak of standardisation of fabrics. Commercially we find fabric names are applied in a free manner, and frequently the name used bears no relationship to any technical classification which might have to be undertaken. We have to allow for considerable variation in structure and textural effect in any class or family of fabrics, and scientific data in relation to fabric structure have not yet been formulated. It is true that the materials used in manufacture are subject to expert analysis, and prior to the final judgment in the hands of the consumer the cloth may have to conform to recognised standards of strength or other property. In this respect a considerable amount of standardisation in the sense of working to given specifications does prevail, but more especially in the production of industrial fabrics. The constructor has, therefore, a dual function to perform in many cases. He must create an effect that will appeal to the consumer, on a fabric that is free from defects arising from wrong selection of yarns or manufacturing processes. Sometimes durability is sacrificed in order to obtain decorative effect, and on the other hand the material may have long life but little ornamental value. In many instances, and especially in those cases where the materials are subject to the judgment of the eye, modern fabrics have greater appeal, but less durability than the fabrics used for the same purposes in former days. But in fabrics of the industrial group the applications of scientific research have produced textures of great utility. This is notably the case in respect of tyre fabrics where the average life of a good tyre has been increased at least three-fold in a comparatively short time, mainly due to an intensive study of the types of stressing the yarns or cords must withstand in tyre service.

Ornamental fabric construction is the domain of the craftsman in weaving just as much to-day with our modern machinery as it was in the early hand-loom days, and as we have indicated, scientific data in this respect have not been tabulated. There are vast fields of cloth construction which will always be developed in an empirical manner, and these products will appeal to the consumer first because of their artistic appearance, handle, and price. It is clear that we are bound to divide our fabrics into two broad classes—(*a*) those for general domestic consumption and (*b*) those for purely industrial purposes. The range of samples available in each class is enormous and obviously beyond the limits of this brief survey. We propose, therefore, to confine our attention to a consideration of examples taken from materials used for modern light dress goods and furnishings, ignoring those which are distinctly industrial in their utility.

The changes which take place in fabric building and the varying uses to which old and familiar structures are applied, can be conveniently described as "change of fashion", and this in turn is a reflection of the changes which take place in the social and economical conditions of the community. Although fashion is said to be fickle, there are often very good reasons for the changes which do occur in the construction or use of fabrics according to its dictates. The fabric builder can seldom create a new fashion, but rather in the majority of cases he must be creative along the lines of fashion. That is to say, the impulse which creates the demand for a new type of fabric will not originate in the mill designs department, but somewhere and under some circumstances very remote from the mill.

Since the war we have had many changes in social and economic conditions which have affected the structure of woven fabrics. Fashion in ladies' dress has changed much more than with men's.

The long flowing skirt, together with a blouse of different material, and under-garment of still different materials, have been replaced by much lighter and shorter garments, and, unfortunately for the weaver, by knitted garments in many cases. These changes are mainly due to the entry of women into wider industrial and commercial life. Short skirts demanded more decorative stockings, and this in turn produced the first great impetus in this country for the use of lustrous rayon yarns as a cheap substitute for pure silk. The immediate post-war years saw the demand for bright colours and high lustre in fabrics, and we had a second development in the use of rayon, either as effect threads in cotton and worsted fabrics or comprising the warp or weft in a union fabric, or again in very lustrous fabrics consisting entirely of rayon. These lustrous fabrics have now a very limited use, being chiefly confined to ladies' coat linings where the smooth, slippery surfaces, and high lustre are desirable. The wider interest in social functions and outdoor life has called for fabrics appropriate for each occasion, and while the time spent in these directions cannot be devoted to domestic duties, we have seen the desire for fabrics which can be easily laundered. This has given the weaver the opportunity to use many novelty yarns in such fabrics as cotton tweeds, sponge and ratine, crêpes and crêpons. Science has finally come to the aid of the weaver and introduced a finishing process which renders the most delicate cotton and rayon fabrics non-creasing, and these materials can now stand the severe test of use as men's tie fabrics. This new discovery is without doubt worthy to rank with that of mercerising cotton for lustre. Open-air bathing has extended the use of negative warp pile materials in brilliant colours, for use as beach robes or bathing wraps

The post-war house with its casement and bay windows of much larger area than the older type has created a demand for more elaborate window furnishings, and the weaver has developed a wide range of decorative materials for this purpose. Lighter rooms have called for brighter furnishing materials which need not possess the durability of the older fabrics.

The starched collar has given place to the soft or semi-stiff one, and in this latter category we have some interesting cotton structures. The standard type of shirting fabric in recent years has been the cotton poplin, and this has replaced the coarser Harvards and Grandrelles almost completely. With a warp ribbed structure of the poplin nature, there is practically no loss of colour strength in the warp threads due to weaving, and a fabric was evolved which had a soft silky handle, a smooth surface, bright colour effects, light in weight, and with excellent wearing properties. It would be of interest to know how much longer it takes a spinner to produce the yarn to make a poplin shirt of good quality as compared with a shirt of Harvard or Grandrelle On the other hand, the poplin cloth is made on a simpler type of loom than the more elaborate zephyr shirting fabric, with its fine jacquard figure, crammed satin stripe, or extra warp stripe The humble corduroy has been replaced by the lighter, more hygienic, and cheaper cotton drill for workmen's clothing, eight or nine yards of which can be woven in the same time as one yard of the fustian. The principle of weaving weft pile fabrics of the corded type, although declining in the heavy sections, was revived for the production of light dress goods with a voile foundation and rayon pile, and in this direction the weaver in conjunction with the finisher evolved some remarkably good effects, which, however, suffered in appearance during wear from the limitations imposed by the nature of the rayon, that is, relative coarseness of the fibre elements, reducing the covering properties as compared with cotton of similar counts, its slippery nature, and its slow recovery when flattened out under pressure.

We have seen in recent years an almost complete reversal in the qualities demanded from rayon in the structure of dress materials. In place of the original high lustre, the fabrics have been toned down until the dull matt effect is the prevailing vogue, and many of the modern all-rayon fabrics show less lustre than mercerised cotton goods, but the structures have a feel and handle entirely their own, together with excellent draping properties. The control of lustre in fabrics containing rayon was first met by the application of twist in the yarns, and we have passed through a phase in which the correct balance of twist was of greatest importance. Indeed, it is still the chief controlling factor producing the effect in many present-day structures. Cloths of the "ray-de-chene" type, consisting of a cotton warp set two twist way, two weft way, of fairly hard-twisted material, crossed with rayon weft of full lustre and practically no twist, produced a fabric with excellent properties at a cheap rate. The slippery rayon was locked firmly in position without "cramming" the picks, and the slightly broken surface of the material reduced the apparent lustre to that of pure silk. I do not know whether the ray-de-chene grew naturally from the pure silk crêpe-de-chene, or whether the value of twist contrast in holding slippery threads was re-discovered, but I consider this fabric to be the basic one upon which the construction of all manner of modern materials composed of (or containing) rayon yarns is founded.

Delicate stripe effects arising solely from differences in light reflection from groups of twist-way and weft-way spun yarns have been fully exploited in cotton poplins and warp satins, schreiner finishing enhancing the effect, particularly in the case of the warp satins. In modern fabrics we find somewhat similar results being secured by combining groups of blanche or matt rayons with lustrous rayon yarns, and there seems to be no limit to the possibilities offered to the weaver in this direction for producing delicate gradations of colour and lustre.

FACTORS CONTROLLING THE STRUCTURE AND APPEARANCE

There are four fundamental factors controlling the structure and appearance of woven textures. These are—(1) the yarn unit; (2) the relative setting of ends and picks; (3) the weave or order of thread interlacing; (4) the nature of the finishing process applied after weaving. Each factor embodies in itself a wide range of variation, and the possible combinations of types and qualities of textures arising from the four groups are without limit.

Yarn Quality

Yarn quality and appearance are in the first place determined by the nature of the raw material used, such as cotton, flax, wool, silk, or rayon; each imparts its own peculiar characteristics to the yarn and through the yarn to the finished cloth. Thus, briefly, cotton and flax are compact and dense in fibre, and the fibres are of small diameter and relatively long in staple, but low degree of lustre, especially the cotton. They are strong, flexible, and durable in wear, and may be applied to structures with clear surfaces of well-defined weave details and firm construction. Silk is characterised by its rich lustre, extreme fineness, strength, elasticity, and smoothness, while wool has the special properties of extensibility, good covering power, and ability to shrink and felt during finishing. There is again the factor of quality in each group ranging from those with non-parallel fibres, to yarns constructed from carefully selected parallel fibres as in combed cotton. In flax we have qualities ranging from coarse "tow" to fine "line", and in the wool groups we have shoddy, woollens, and fine parallel-fibred worsted. In silk and rayons we have yarns composed of continuous filaments. Each quality of yarn has clearly defined limits of application in respect of standards of strength and other physical properties in cloth building, and quality is a determining factor in the closeness of the setting that can be achieved in warp. Again, yarn quality determines the appearance of the fabric in many cases.

The Twist Factor

The twist factor is of great importance in the structure and appearance of the fabric. Normally the amount is determined by the fibre length and diameter, and as a general rule the longer and finer in diameter the fibre, the less twist is required to make an average commercial yarn. Twist largely determines the lustre and covering powers of the yarn, and clearness of weave details in the fabric, while excess of twist leads to harshness of feel and shrinkage or crimping of the cloth. The degree of twist is of great importance, because many effects are dependent upon the contrast between yarns spun with different twist constants and directions. It is well known, of course, that the amount of twist inserted into a given quality of yarn determines the degree of shrinkage which can be obtained in a given structure of cloth, but no one can say with certainty what the ultimate result will be from a change in any one of the factors arising in the construction of the yarn or the fabric. For example, a long-fibred cotton will produce a different shrinkage coefficient from a short-fibred one, with the same count of yarn and twist constant, and the number of filaments composing a viscose rayon thread has a somewhat similar bearing upon the crêping properties of the yarn. Again, it is obvious that the count and closeness of the setting in the warp will control the amount of shrinkage in width of fabric due to the use of hard-twisted weft, and it is of interest to note that the degree of shrinkage is different when the fabric is picked, two twist way, two weft way, as against the weft being all one direction of twist.

The appearance of the fabric is also different in the two cases. The single-weft picking produces a cockled surface which tends to fall into regular lines running parallel with the selvedge, while the use of two wefts with the different directions of twist gives a flatter surface. The first is generally called "Crêpon" while the second is described as "Crêpe".

A novel development, based upon "Crêpon", is to pick a fabric with groups of hard-twisted wefts, say 16 picks of twist way followed by 16 picks of weft way. On shrinking a cloth built in this way it is found that the two groups of weft tend to oppose one another in their crimping, and give a blistered appearance to the surface, the material being popularly known as "Elephant Skin".

An experiment was carried out to show the effect of the amount of twist in weft upon shrinkage in cloth width—

Weft yarn, 20's nominal count from 1⅛ in. American cotton, was spun with twist constants ranging from 3·5 to 9 √count.

A plain cloth, 52 ends per inch in reed, 1 per dent of 2/60's cotton, was woven with 42 picks per inch.

Strips 12 in. long were woven alternately from (*a*) two twist way, two weft way picking, and (*b*) all one direction of weft twist.

The fabrics were measured for width after leaving the loom and also after wetting-out in boiling water for 30 minutes, and allowed to dry without tension.

The following results were obtained—

Twist constant ...	3·5	4·0	4·5	5·0	5·5	6	6·5	7·0	8	9
Per cent. loss width										
(*a*) 2 × 2 pick ...	2·5	2·8	3·3	5·2	10·0	16	23·8	26·2	37	45·5
(*b*) Single pick ...	1·8	2·5	4·4	6·6	11·4	18	25·6	29·6	38	41·0

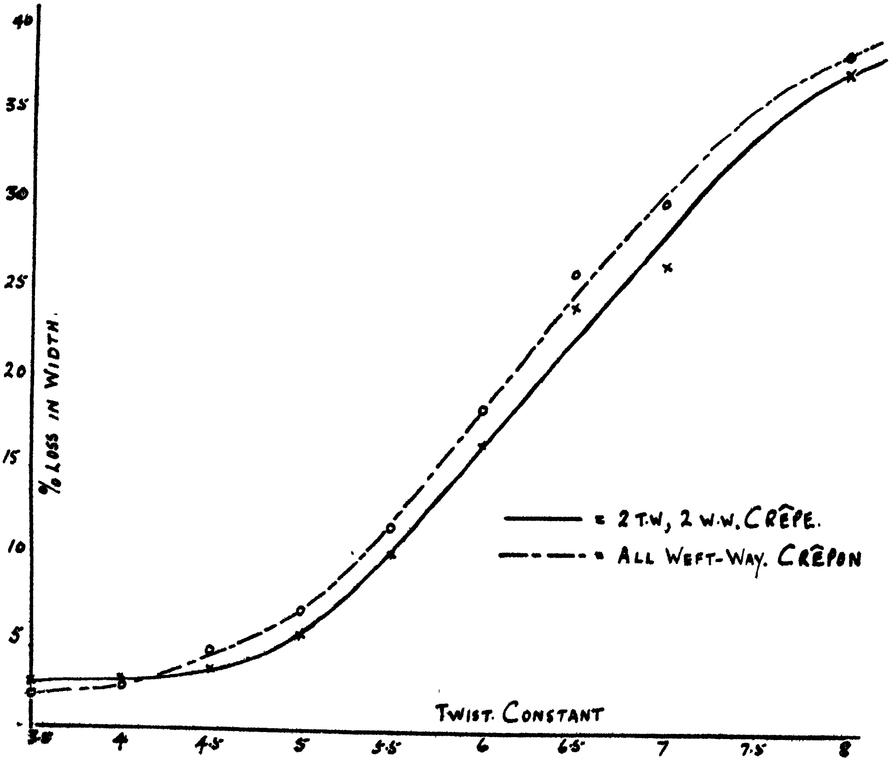
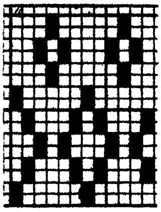


FIG. 1

The curves (Fig 1) show that between twist constants 5 to 8 there is an almost uniform rate of shrinkage so far as this particular structure is concerned, and that the Crêpon shrinkage is greater than the Crêpe.



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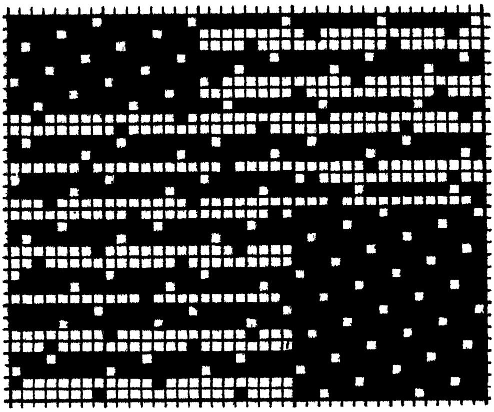

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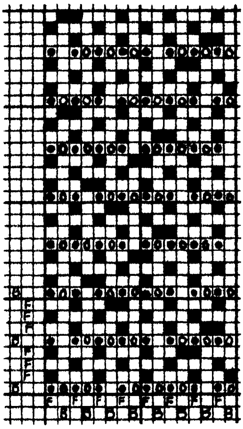

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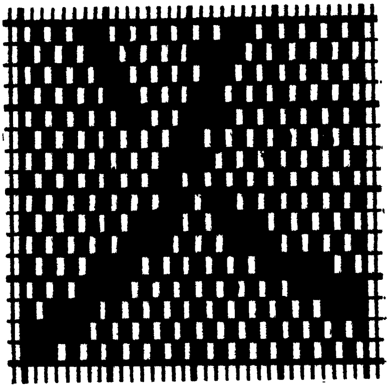

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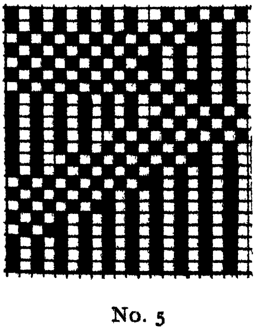

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Motif
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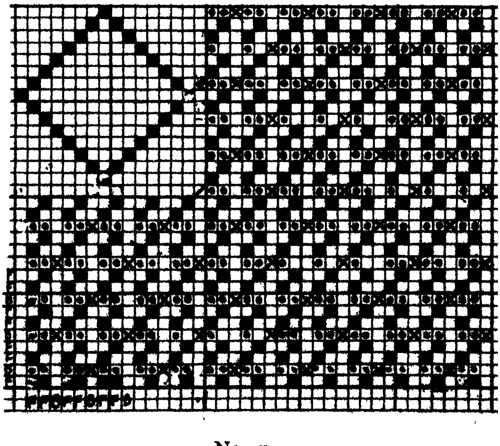

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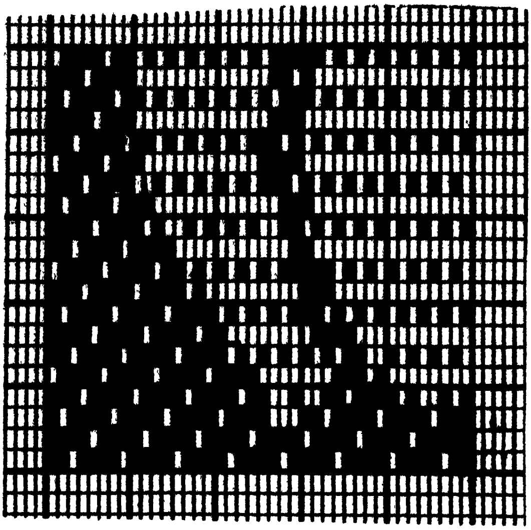

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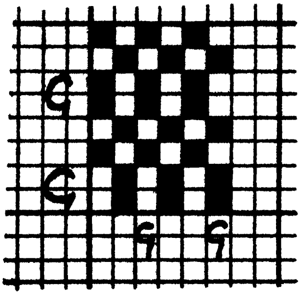

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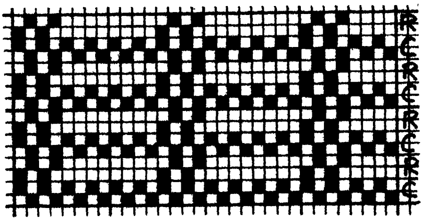

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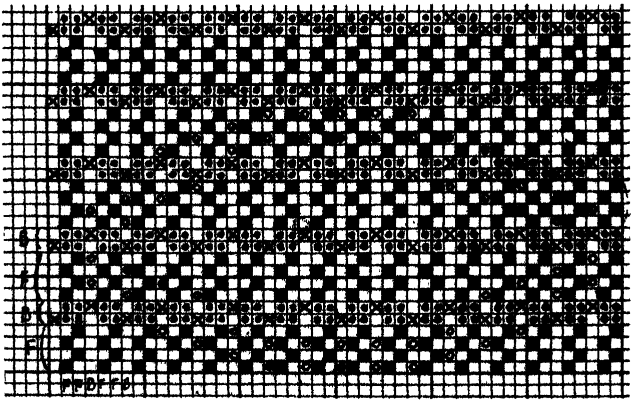

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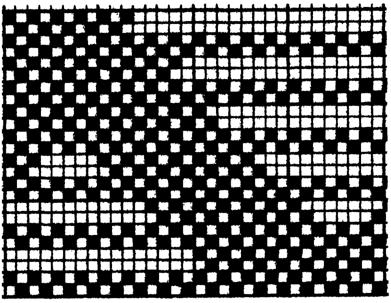

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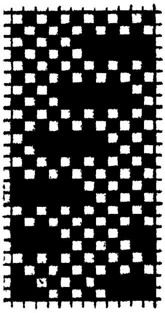

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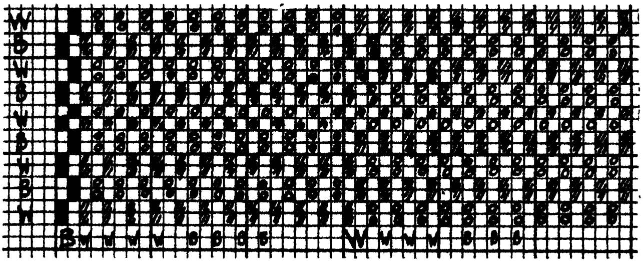

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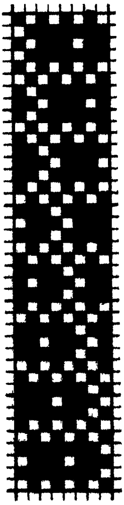

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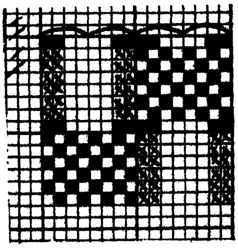

No. 16

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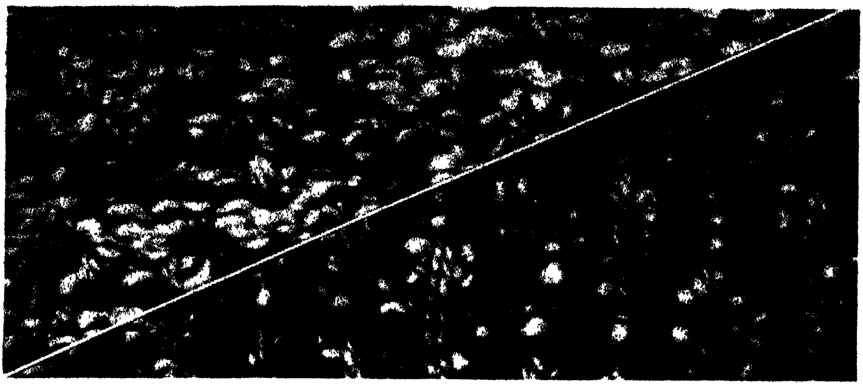

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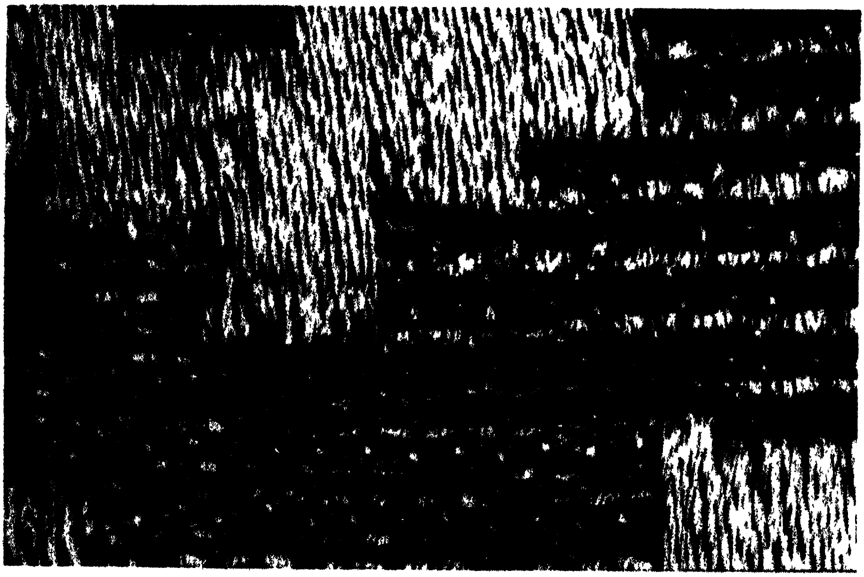


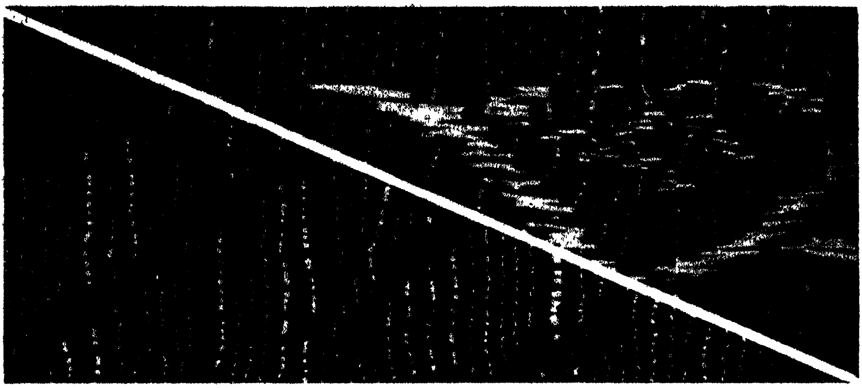
Sample No. 2 (× 2)

Sample No. 3—Face (× 3)

Sample No. 3—Back (× 3)

PLATE I

Sample No. 4—Face (×2)



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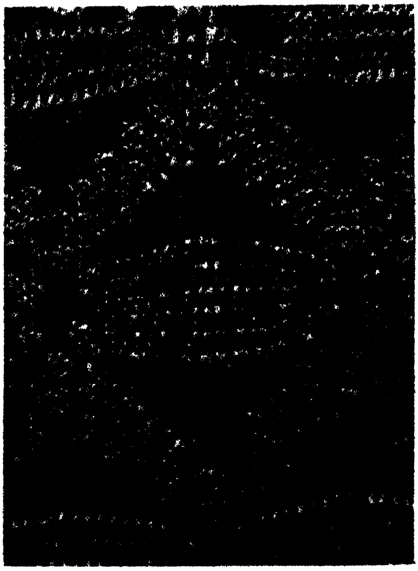

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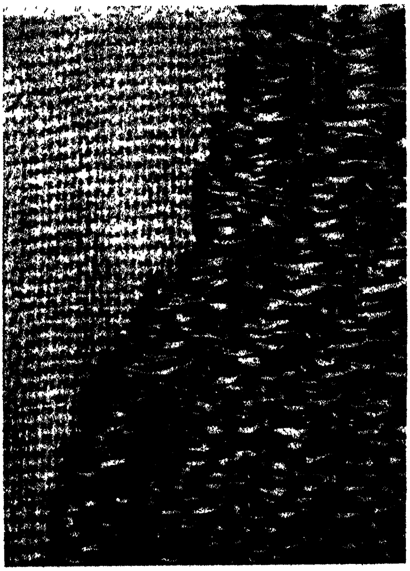

Sample No. 6 (×3)

Sample No. 7—Face (×3)

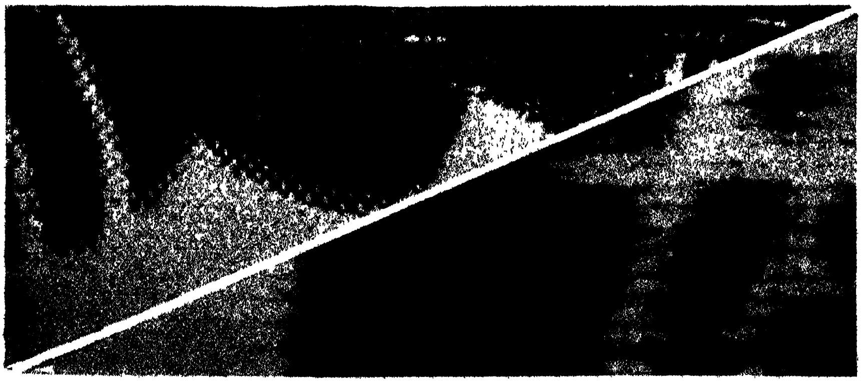

PLATE II

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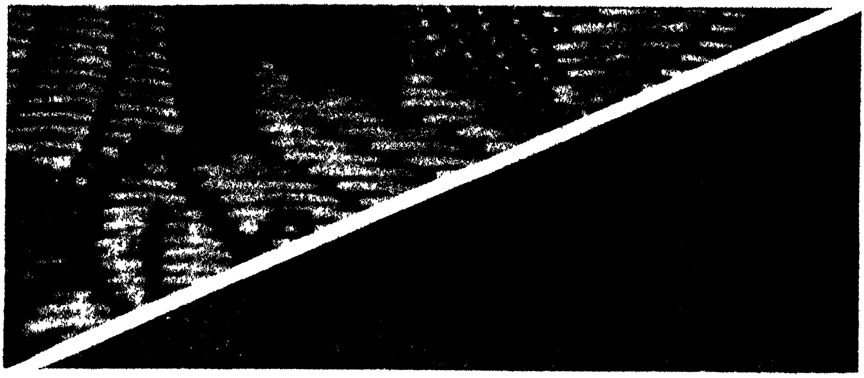
Sample No. 8—Face (×3)



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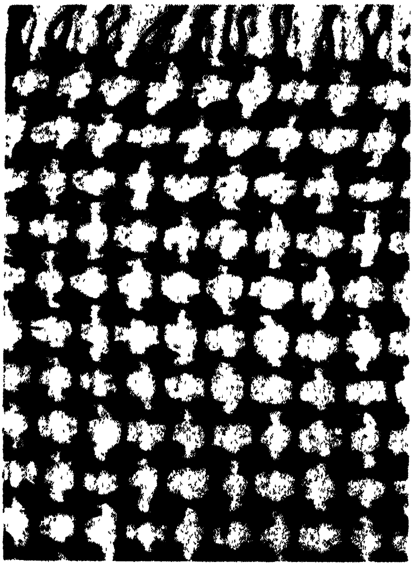

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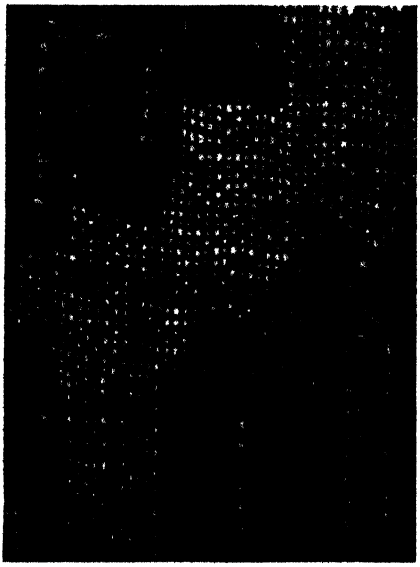
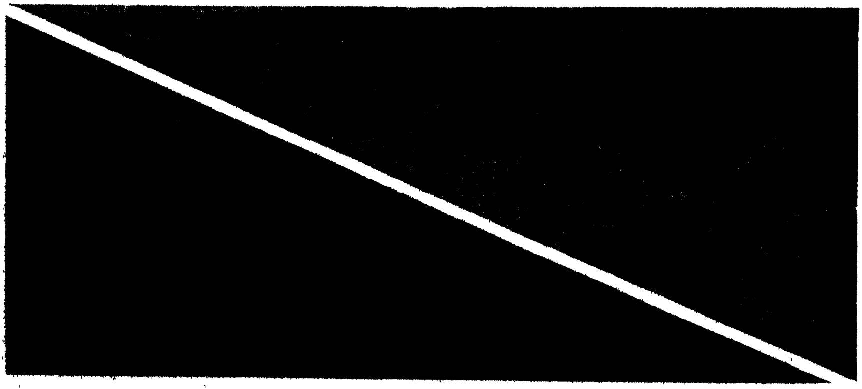


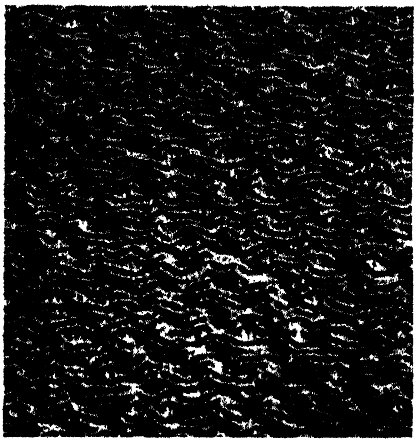
Sample No. 10 (×3)

Sample No. 11—Face (×3)



Sample No. 11—Back (×3)

PLATE III



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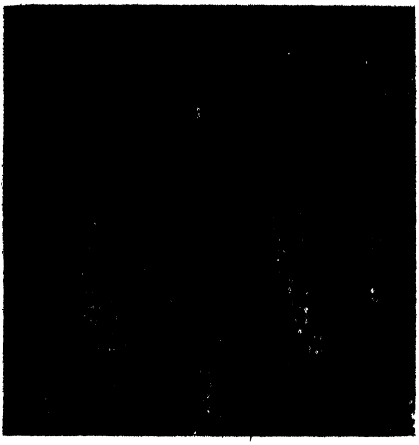

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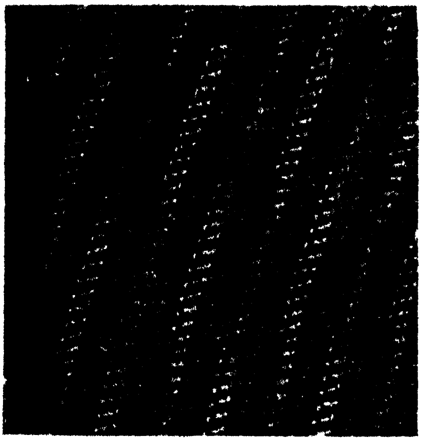
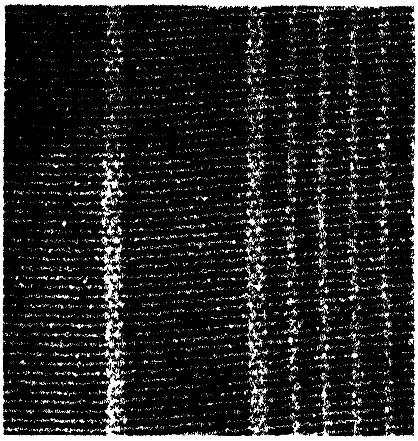


Sample No. 14 (×3)



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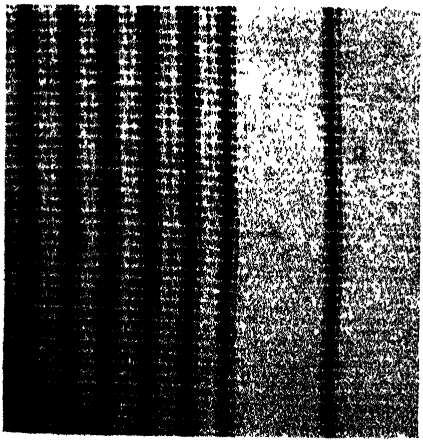

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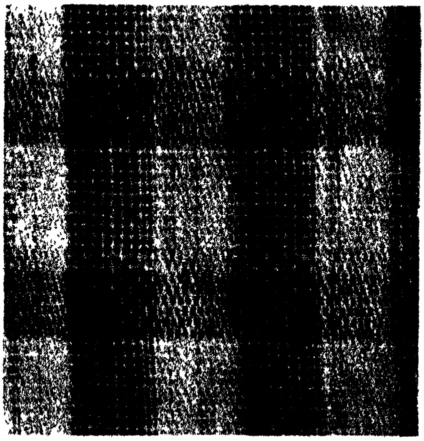
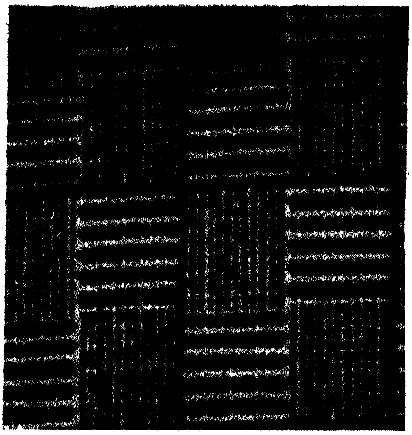


Sample No. 17 (×3)

PLATE IV



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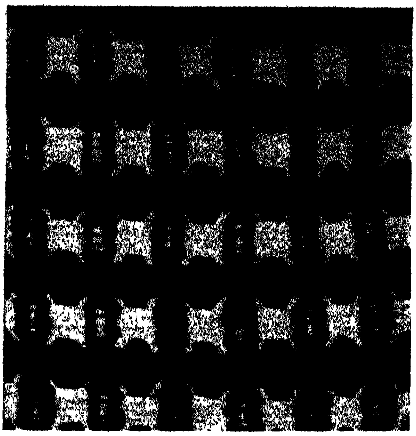

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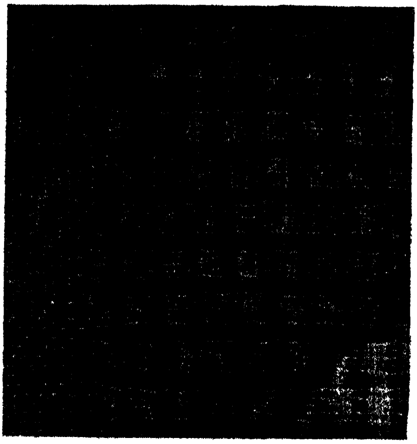

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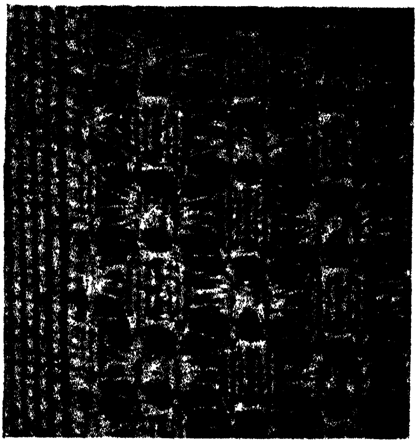

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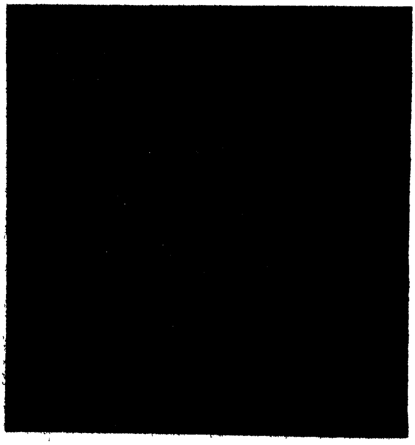
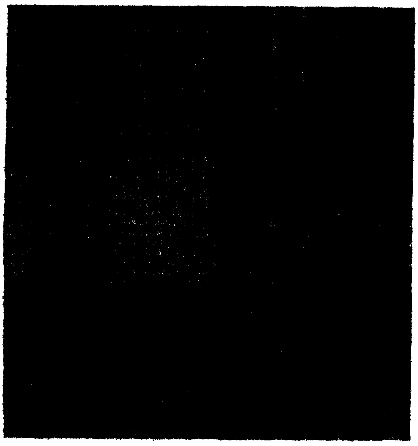


Sample No. 22 (×3)



Sample No. 23 (×3)

PLATE V

TWISTLESS AND DE-TWISTED COTTON YARNS

A modern development in cotton yarns is the production of a thread without any twist. Two types are being produced but are not available in large quantities. In the older type (patented in 1918 by Myers) there is a residue of twist in the yarn amounting to 2–3 turns per inch on the average, but in the more recent product, that is the "Rayallen" yarn (Patent 361,037, November 1931, Allen), we have a cotton thread produced without the insertion of any twist, the principle being that as the fine strand of rove is delivered by the draw rollers, it is impregnated with an adhesive mixture, rolled into a cylindrical body, dried, and finally wound on to a suitable container. The yarn has virtually no twist whatever. The materials are best used as weft because they have no elastic properties in the sized condition and, of course, no strength without the adhesive and prior to fabrication. The advantages of such yarns are that as they have better covering powers, so a reduction of some 20% can be made in the picks per inch, greater lustre especially if the fabric is mercerised, softer handle and good draping properties, easier to dye, print, and waterproof, and give a good napping surface when such is desired

Twistless yarn gives excellent results in limbrics and weft spot effects when the fabrics are mercerised, and also in velveteens and cords. The fabrics have a high lustre equal to that of spun silk, and in the case of the limbrics, not very much inferior to that of "ray-de-chene" woven with full-lustre rayon weft. The strength of the fabric is not materially impaired by the use of these wefts. The comparative structures of two limbrics examined were as follows—

Ordinary weft yarn	74/102	70/36	weight ·178 lb. square yard
Twistless „ „	72/82	50/34	„ ·167 „ „ „

The following experiment was carried out with a view to comparing a de-twisted weft with an ordinary commercial weft of good quality and equal count.

A sample of de-twisted yarn (Myers' type) of nominal 17's count with the adhesive on it, gave the following results when tested—

Mean strength, single thread, 100 tests, 10·84 oz. with a variation of ± 12·6%

A good quality of ordinary commercial yarn of 17's count gave a mean single-thread strength of 10·05 oz., with a variation of ± 7·46% over 100 tests. The relative extensibilities were 1·3% for the de-twisted and 5% for the ordinary yarn, on 18-in. samples placed into the lower grip of the tester, under a constant load of 110 grains, and the lower grip moving at the rate of 12 in. per min.

The yarns were woven into a plain cloth having 64 ends of 2/56's cotton and 64 picks per inch. Strips of 100 picks wide were prepared with ¼-in. fringes at each side. These were tested on a Goodbrand's machine, 4 in. between the jaws and moving at the rate of 18 in. per min.

The following results were obtained—

Cloth Strength (Weft Breaks)

Ordinary commercial weft ...	24 tests	mean strength	103·3 lb.
De-twisted weft (with adhesive)	16 „	„ „	125·6 lb.
„ „ (desized) ...	16 „	„ „	118·1 lb.

Small samples of cloth were also mercerised and dyed, and the de-twisted samples were superior in lustre and depth of colour.

Fancy or effect yarns, such as slubs, gimp, and corkscrew, are available in great variety, and play a very important part in modern fabric structure. They produce rough broken surfaces which distort or completely hide weave details, but offer excellent contrast to smooth and more lustrous yarns. They are, however, relatively coarse in counts and therefore heavy units to apply, especially in conjunction with fine count yarns in the form of stripes or check. Many modern furnishing and casement fabrics have these classes of yarns incorporated in their structure. Four samples are shown in fabrics 1, 2, 3, 4, their methods of application being given in the accompanying specifications and designs. Sample 9 is a modern cotton dress material in which gimp yarn is an important feature.

A modern feature in respect of rayon fabrics is the contrasting of blanche and lustrous yarns in the form of stripes, and two examples are shown in fabrics Nos. 14 and 15. In each case crêpe wefts are used to prevent sliding of the rayon warp threads.

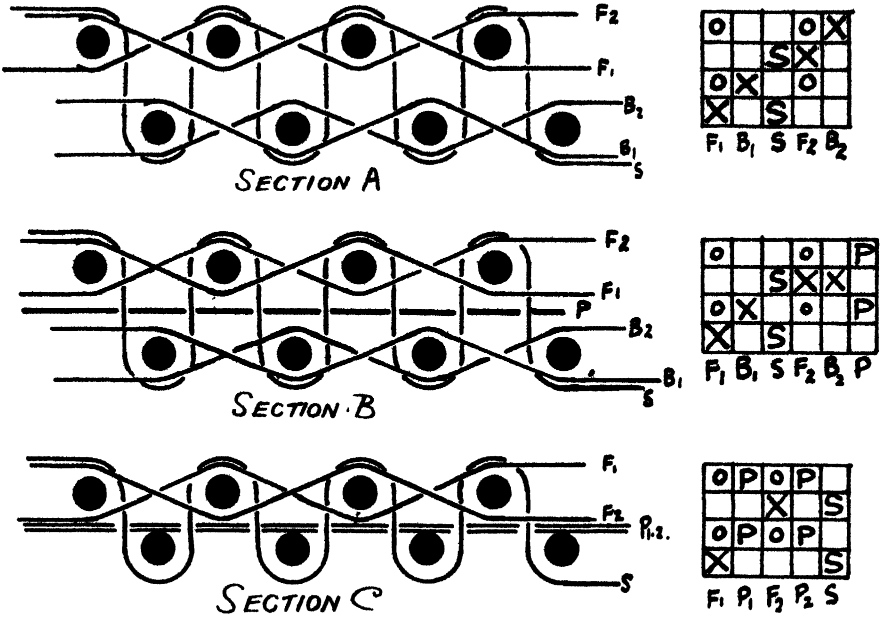


FIG. 2

YARN SETTINGS AND WEAVES

The relationships between the yarns, ends, and picks per inch, and the order of interlacing the threads in a fabric might be compared with the bricks and mortar which are used in the creation of a building to the architect's specification. The general appearance and utility of the cloth depends upon the correct correlation of the elements according to the effect which the designer has in mind. Thus the fabric may be a balanced structure, or it may have one set of yarns predominating either in respect of count, lustre, colour, or density of setting, or again, the fabric may be an open texture as in the case of voile or gauze, where the clear open spaces between the threads are as valuable as the threads themselves in the appearance of the fabric. Probably the most densely woven cloths for domestic use, made from cotton yarns, are those employed for semi-stiff collars. They are compound structures ranging in weight from 0·5 to 0·9 lb. per sq. yd., and are constructed in the different ways shown in Fig. 2, sections A, B, C, to the approximate settings given.

Structure A

80 Face ends 2/70's, 80 back ends 2/70's, 40 stitch ends 2/60's, 120 picks 2/60's per inch. The stitch warp has a regain of about 270% and the weight of tha fabric is about 0·57 lb. per sq yd.

Structure B

82 Face ends 2/52's, 82 back ends 2/52's, 41 padding ends 2/24's, 41 stitch ends 2/52's, 120 picks 2/50's, stitch warp regain 280%, weight per sq. yd. 0·9 lb.

Structure C

84 Face ends 2/60's, 84 padding ends 2/30's, 42 stitch ends 2/54's, 114 picks 2/60's, stitch warp regain 276%, weight per sq. yd. 0·78 lb.

Other very closely woven cotton fabrics of fine texture are used for light garments that shall be waterproof, windproof and stormproof, and these have been found to be excellent materials to wear in very cold and stormy climates. The "Grenfell" cloth is an excellent example of these light fabrics. In general they are woven three or four-end twill with about 200 ends and 100 picks per inch, of fine quality combed two-fold yarns, giving a weight of 0·3 to 0·4 lb. per square yard.

Another very dense structure, composed of cotton yarns, is illustrated by sample No. 8. This is a corset cloth with a five-end satin ground, woven with 170 ends per inch of 2/60's mercerised warp and picked alternately with 300 denier rayon and 2/50's cotton at the rate of 80 picks per inch, producing a cloth with a weight of about 0·47 lb. per square yard. The fabric is very strong and somewhat stiff in handle, and is ornamented by floating the rayon weft on the face according to pattern. Density of structure is maintained behind the figure areas by weaving in plain order with the cotton warp and weft as shown in the part design Fig. 8.

There have been many theories expounded to determine how closely threads of a given count can be placed in a woven structure, but one frequently meets with samples of cloth which exceed the limits imposed by the theoretical formulæ. Yarn density, loom rigidity, and strength, to say nothing of yarn qualities, are unknown factors which have an important bearing upon possible density of setting in cloth.

For example—an actual piece of 2×2 twill fabric contains 196 ends of 2/80's and 90 picks of 2/90's mercerised yarns. The "diameter number" of these yarns, allowing for the effects of mercerisation can be taken as 183 and 194 respectively So far as the warp is concerned, we actually have 13 ends per inch more than it is assumed can be placed side by side on a flat surface 1 in. wide, and the picks stand at almost 50% of the diameter number. Careful inspection of this cloth reveals the fact that the warp threads are crimped or distorted in two directions (*a*) in the vertical plane by passing from face to back of the cloth as is usual in all fabrics, and (*b*) in the horizontal plane due to the side pressure of the adjacent end, and the cloth assumes a thickness that is equal to the sum of the diameters of two warp threads and the weft thread, whereas normal structures are equal in thickness to the diameter of the warp yarn plus the diameter of the weft.

EXAMPLES OF MODERN STRUCTURES

As previously stated, the fabrics which compose the domestic group are subject to the judgment of the consumer's eye, sense of touch, and opinion as to general fitness for the purpose intended in wear. Ornamentation is of the first importance, and so far as this is developed in weaving, it consists of the correct combination of threads in the weave, and in colour, count, and lustre, in order to produce a pleasing effect. Successful structures are the product of craftsmen of no mean order.

The accompanying fabrics and structural specifications are examples of modern work.

Furnishing Fabrics

Sample No. 1—A reversible casement or hanging.

50 Ends per inch of 2/18's cotton.

25 Picks per inch of 3·7's cotton gimp, reinforced with a thread of 2/30's cotton wound on to the pirn along with the gimp.

Weight per square yard 0·76 lb.

Weave pattern on six shafts. Design Fig. 1. Warp pattern—3 brown, 1 orange, 3 brown, 1 green, 3 brown, 1 blue.

Sample No. 2—Tapestry casement.

104 Ends per inch of 2/150 denier viscose rayon, warp printed before weaving.

24 Picks per inch of four wefts, viz. 1 pick 5's brown condensor, 1 pick 2/5's green condensor, 1 pick 2/fold gimp blue and drab 2's count, and 1 pick 2/fold dark brown and light brown gimp 2's count. Rayon figure developed in 8-end warp satin, ground weft floats bound in 12 sateen order. Part design Fig. 2.

Weight per square yard 0·68 lb.

Sample No. 3—Reversible compound furnishing fabric.

Cotton and rayon face, cotton gimp back.

36 Face ends of 2/60's cotton, dyed and warped to pattern.

36 Back ends of 2/32's black cotton

57 Face picks of 150 denier blue rayon

19 Back picks of 3's cotton gimp.

The blistered surface is produced by binding into the face cloth with the back warp according to design, Fig. 3, on 12 shafts.

(Solid squares = face weave, circles = back weave, dots = face warp lifted on back picks.)

Weight per square yard 0·52 lb.

Sample No. 4—Brocaded Furnishing Fabric.

This sample is made with a 150-denier rayon warp, 104 ends per inch, and 32 picks of 2/fold cotton-slub weft about 3½ count, so that the weight per square yards is 0·5 lb. The figure is developed in rayon warp floats on a plain ground, and excellent contrast is obtained as between the face and the back of the fabric. The slub weft produces a distorted ground effect which stands out as lustrous horizontal lines on both sides of the cloth, and whereas on the face we have a lustrous figure, we obtain a very dull figure effect on the reverse side. Part design is given at Fig. 4.

Sample No. 5—Light casement fabric.

96 Ends per inch of 150 denier rayon.

44 Picks per inch 12's cotton.

In this fabric a warp figure is developed on both sides and the sample can be woven on 14 heald shafts. Considerable distortion of the weft occurs and this enhances the figure effect.

Part design, Fig. 5. Weight per square yard 0·29 lb.

Sample No. 6—This is a light casement fabric with a cotton ground of plain weave and an all-over rayon figure developed on one side by lappet weaving.

The novel feature is the almost complete covering of the ground fabric by the lappet effect.

Sample No. 7—Compound rayon and cotton printed dressing gown fabric with raised back (low quality).

Rayon face, 74 ends of 100 denier and 54 picks of 150 denier.

Cotton back, 37 ends of 30's and 27 picks of 6's condensor

Weight per square yard 0·38 lb.

The two plain fabrics are stitched together by dropping rayon face ends on alternate back picks Three alternate face ends constitute one stitch. Fabric woven on 12 heald shafts. Design Fig. 6 shows the motif and Fig 7 shows part of the structure, which repeats on 168 ends and 84 picks.

Sample No 8—Corset fabric.

170 ends of 2/60's white mercerised cotton.

40 Picks of 2/50's pink mercerised and 40 picks of 300 denier pink rayon.

Weight per square yard 0·47 lb. Part design Fig. 8 (cotton face = 5-end warp satin; figure = weft floats in rayon; behind figure, plain weave with the cotton weft).

Sample No. 9—Blue and white cotton dress material with gimp warp and weft.

14 ends of 6's gimp and 28 ends of blue 36's per inch.

24 Picks of 13's gimp and 24 picks of blue 34's per inch.

Weight per square yard 0·27 lb. Design Fig. 9. (G=gimp yarns.)

Sample No. 10—Figured rayon weft pile on cotton voile ground.

64 Ends per inch 2/90's voile yarn.

58 Picks per inch 2/90's voile and 58 picks of 150 denier rayon, picked 2 cotton 2 rayon.

Weight per square yard of finished cloth 0·164 lb. Part design Fig 10.

EXAMPLES BUILT FROM FLAT RAYONS IN CONJUNCTION WITH CRÊPING YARNS

Sample No. 11—This is a fabric with a blanche celanese face warp and weft woven in plain cloth order, backed with crêpe viscose warp and weft. The crinkled surface is obtained by stitching into the face cloth with the back ends as shown in design No. 11, and the fabric allowed to shrink in finishing. The design shows one spot unit, and these are set out in 8-end satin order on 96 face and 48 back ends, and 64 face and 32 back picks. The fabric has 116 face and 58 back ends, and 72 face and 36 back picks per inch in the finished state. Full squares=plain face weave; X=plain back weave; dots=face ends lifted on back picks; O=binding points.

Sample No. 12—Is a rayon and cotton crêpe fabric with celanese "blanche" warp yarn picked with cotton crêpe. Plain weave, with the following loom particulars—112 ends, 100 denier celanese blanche, 49 picks of 3/72's cotton crêpe, picked 2 twist way, 2 weft way

Sample No. 13—This is a blister cloth developed on the Bedford cord principle and woven with 75 denier blanche celenase warp 123 ends per inch, and picked, 2 picks 50's cotton crêpe and 2 picks 100 denier celanese blanche, with 80 picks per inch. The design repeats on 48 ends and 52 picks; portion developed in Fig. 12.

Sample No. 14—Is a twilled pattern developed on the Bedford cord principle as design No. 13, with the warp arranged 12 blanche and 12 lustre rayon, 132 ends per inch in the finished cloth, and 88 picks of 2 twist way and 2 weft way rayon crêpe weft.

A delicate shadow stripe effect is produced, which appears to stand out in broken lines according to the draping of the fabric.

Sample No. 15—Is another application of blanche and lustrous rayon warp yarns arranged in the form of shadow stripes. Plain weave, 110 ends of 100 denier celanese blanche and lustre, with 60 picks of 150 denier viscose crêpe, 2 twist way, 2 weft way.

Samples Nos. 16 *and* 17 are modern cotton dress materials of high quality in which the effect is obtained by irregular denting of the warp yarns. No. 16 is known as "pique voile"; the yarns are of voile quality but the weave has no relationship in any respect to pique. Sample No. 17 is an excellent check effect, involving irregular denting as in the pique voile, and is picked in the following order—10 white, 2 royal blue, 4 sky, 2 light blue. The combination of the denting of warp and the weft pattern as above produces a good tone effect in blue and white.

Sample No. 18—This is a modern shirting built on the poplin style in which a smart check effect is produced by the blending of brown and white warp and weft, over-checked with stronger lines of brown. The warp pattern is as follows—

White	1		2	1		
Light brown ...		1			1	
Dark brown ...						2
	11 times			11 times		

The weft pattern is 2 white, 2 light brown, 10 times, followed by 2 white, 2 dark brown.

The checking pattern produces the following blendings of colour—(*a*) white warp crossing brown weft, (*b*) brown warp crossing brown weft, (*c*) white warp crossing white weft, and (*d*) brown warp crossing white weft. Part design Fig. 14.

▦ = white warp O = light brown warp ■ = dark brown)

Sample No. 19—Is a modern sports shirting of the cellular or leno type. It is picked in the order—4 brown, 4 white, and the warp pattern consists of 4 white, 4 brown.

Sample No. 20—This is a light printed cotton dress material made with voile yarns and having a modified mock leno weave as shown in design No. 15. The pattern repeats on 8 ends and 40 picks, and gives a diagonal setting to the mock leno, which tends to balance the tension on the warp threads and thus enhances the draping properties of the cloth; 120 ends and 70 picks per inch.

Sample No. 21—Is another modern application of the leno weave for a light cotton dress material with 52 ends and 66 picks per inch.

The leno is 2 ends crossing 2 ends, and the design is shown in Fig. 16. X= crossed sheds.

Sample No 22—Is a lighter cotton dress material in which an open leno effect is contrasted with a solid blue spot of extra weft The fabric has 108 ends and 72 ground picks per inch.

Sample No. 23—This is an interesting gingham check made with cotton yarns 80/68, 36/32, in which a natural distortion of the picks is produced by changing from plain weave in the body of the fabric to 2/2 matt where the nine lines of colour of warp cross the nine lines of colour in weft. The tighter areas of plain weave compress the slacker areas of matt weave thus giving slight distortion of the picks.

Fabrics containing Elastic Yarn

The use of strands of elastic in fabric building has been practised for many years. but recently, however, a new development has taken place in the making of elastic threads. They are now produced on the continuous spinning principle instead of being cut from sheets of rubber having a maximum length of about 65 feet. In addition to the advantage of increased length of thread the material is spun into very fine diameters, one maker being capable of producing as fine as 50 denier. The rubber core is cabled with threads of cotton, silk, or other material and the nature of the cabling determines the degree of elongation of the yarn. This ranges from as low as 65% to 225% while an elongation of 100 to 150% is more general. The yarns are about 15% finer in gauge than the corresponding counts in cotton, and they are being used in conjunction with yarns composed of all the other natural and artificial fibres for corsets, bathing costumes, dress fabrics, hosiery, men's clothing, cushion covers and drapery, etc. The degree of elasticity imparted to the fabric depends upon tension or degree of extensibility at which the elastic strands are inserted, and the freedom with which the other threads will permit the stretched elastic to recover its normal state. It is usual to have only about 10 to 20% of the picks of elastic, and in general the greater the extensibility of the fabric the rougher is its surface.

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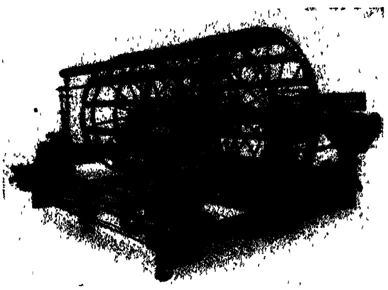

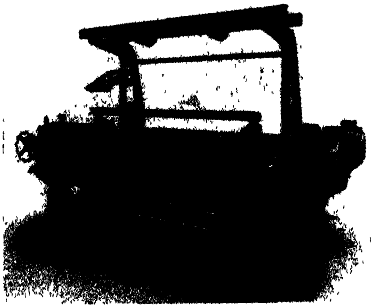

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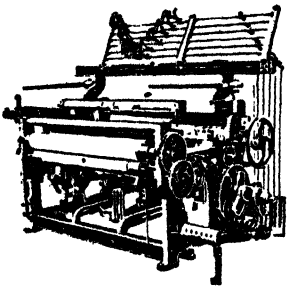

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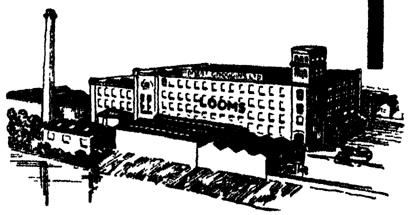

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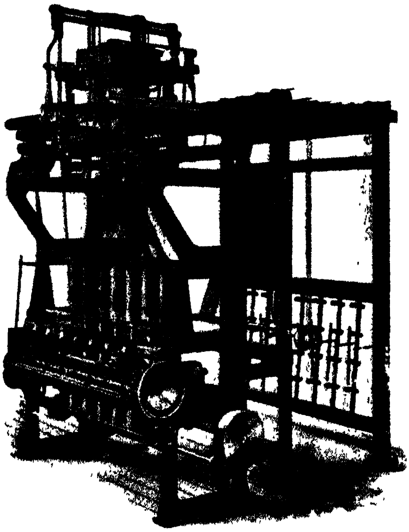

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SOME EXPERIMENTS AND OBSERVATIONS IN CONNECTION WITH TWIST WINDING

By G. A. BENNETT, M.Sc.Tech., M.A.(Com.), A.T.I.

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INTRODUCTION

The main object of twist winding is to wind yarn from cops or ring tubes into larger packages and so put it into a more suitable condition for the subsequent warping process. The vertical-spindle winding machine which winds the yarn on to a flanged wooden bobbin is the type of machine usually favoured, but of recent years cone and cheese winding machines of various types have been increasingly used. The speed of winding spindles and the number of spindles per operative vary greatly in different mills, and in many cases appear to bear little, if any, relation to the class of work being done, since variations in practice can be found between mills engaged on similar counts. For example the spindles of the vertical spindle winder are sometimes run at 600/700 revolutions per minute and the operative attends a large number of spindles. In other cases the spindle speed is as high as 1,200 r.p.m. and the number of spindles per operative is reduced. Generally, however, spindle speeds range from 700 to 900 r.p.m. and the number of spindles per operative varies from 50 to 30.

With a view to discovering the reasons, if any, for these variations in practice and to finding suitable conditions for the winding of cotton warp yarn a number of experiments have been made. These had as their object—

(1) The measurement of the tension in the yarn during winding—

  (*a*) From the nose of a ring bobbin.

  (*b*) From the side of a ring bobbin.

(2) The comparison of the breaking load and extension of yarn before and after winding.

(3) The study of yarn breakages during winding.

1 (a) Nose Winding

The first of these experiments was an attempt to measure the tension in a yarn unwound from the nose of a ring tube and wound upon a warper's bobbin at the vertical spindle winder. A 34's twist yarn was used, the yarn being tensioned by a flannel-covered drag board and then passed through a clearer. Tension in the yarn was measured by a tension recorder placed between the drag board and the clearer. See Fig. 1.

It was found that the tension in the yarn altered rapidly according to the position of the coils of yarn upon the ring tube from which the yarn was being unwound. The yarn tension was greatest when the yarn was being taken from the smallest diameter at the extreme nose of the tube, and decreased as the diameter of the tube increased. Owing to the very rapid changes in yarn tension as the coils of yarn moved from the nose to the shoulder of the tube it was not found possible to measure these. During winding the weight on the lever of the tension recorder was adjusted so that the lever was kept floating in a horizontal position. The instrument thus gave a measure of the yarn tension between the rapidly recurring maximum and minimum tensions due to the varying diameter of the ring tube.

Fig. 2 shows the forces acting upon the lever of the tension recorder as the result of which it was kept in a horizontal position—

T and T_1 are the tensions in the yarn which are equal if friction between the yarn and the lever at A is neglected. The resultant, R, of these forces acts at an angle of 5·5° from the horizontal. The values of R must be such that $Rx = Wd +$ friction at the fulcrum (F) of the lever. On account of the small angle at which the resultant, R, is acting there is pressure at the fulcrum. The value of the friction due to this pressure was taken into account, the values of R being found experimentally and plotted against the distance *d* of the weight W from the fulcrum F of the tension recorder. By measurement from the parallelogram of forces $T = 2{\cdot}81\ R$.

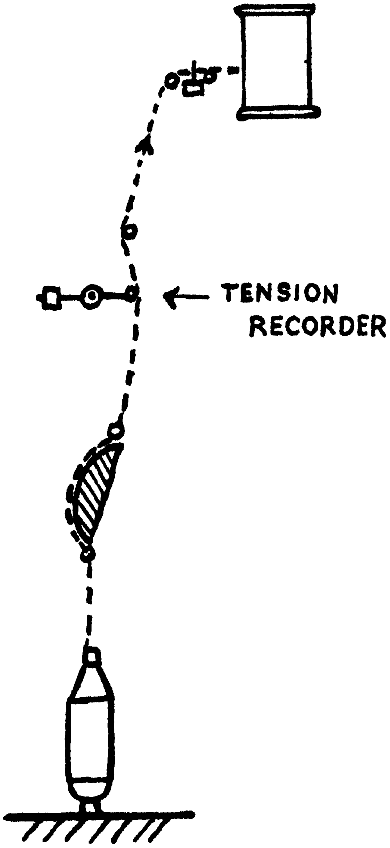

Fig. 1

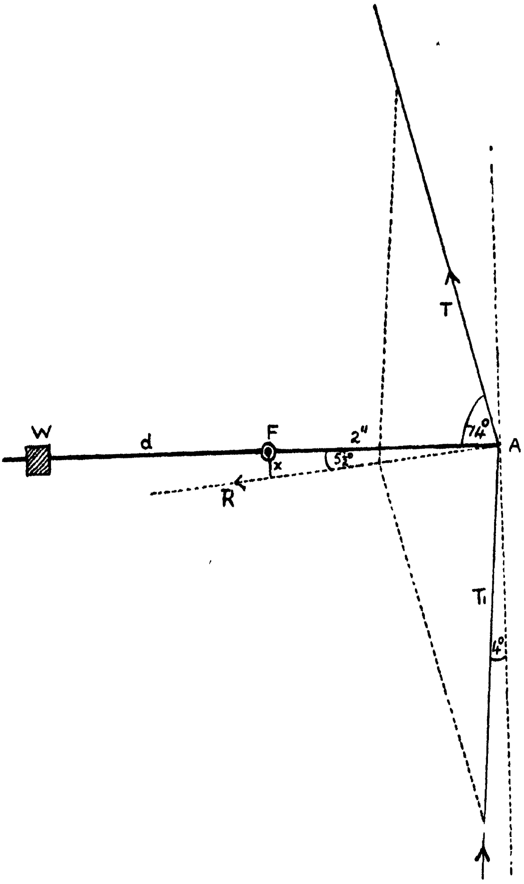

Fig. 2

It was found that during the unwinding of a ring bobbin the value of the yarn tension (T) increased as the ring bobbin emptied; three readings were therefore taken for each ring bobbin—

The first reading was taken when unwinding from the beginning of the bobbin.

The second reading was taken when unwinding from the centre.

The third reading when unwinding from the base.

The values of T obtained during the winding of a warper's bobbin were calculated as follows—

Weight on lever (W) = 0·35 oz.

Distance of weight from fulcrum = 3 in.

The value of R to equal W*d* + friction at the fulcrum of the lever was found experimentally to be 0·105 lb., thus the value of $T = 2{\cdot}81 \times 0{\cdot}105$ lb. $= 4{\cdot}72$ oz.

The values of T for different yarn winding speeds are shown in the following table and graph, Fig. 3—

Table I

Ring Tube No.	Yarn speed, yds./min. At start of tube	In centre of tube	At finish of tube	Yarn tension, ozs. At start of tube	In centre of tube	At finish of tube
1	217·8	235·1	254·1	2·69	3·64	3·91
2	254·1	291·6	326·7	2·69	3·64	4
3	326·7	349·2	370·3	2·88	3·82	4·41
4	370·3	392·9	413·8	3·28	4·09	5·08
5	413·8	433	450·1	3·51	4·14	5·53
6	450·1	462·7	471·9	3·51	4·72	5·40
7	471·9	488·9	500·9	3·69	4·72	5·66
8	500·9	516·8	530	3·51	4·32	6·38
9	530	550	566·3	3·51	4·36	6·38
10	566·3	577·9	588·1	3·78	5·13	7·55
11	588·1	607·6	624·4	3·78	4·95	8

Ring tube—

Diameter (minimum)	0·8 in.
,, (maximum)	1·4 in.
Weight (empty)	0·75 oz.
,, (full)	1·75 oz.
Length of lift	5 in.

Warper's bobbin—

Diameter (minimum)	1·24 in.
,, (maximum)	4 in. approx.
Lift	4½ in.

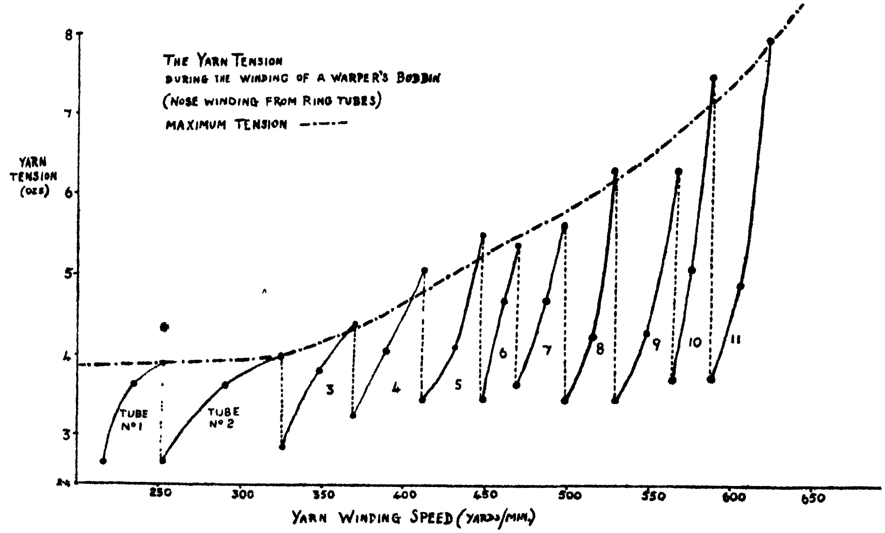

FIG. 3

It will thus be seen that the yarn tension increases as a ring tube is emptied and also increases as the winding speed increases on account of the increasing diameter of the warper's bobbin. The 34's twist used in the experiment had a mean breaking load of 7·55 oz., and the minimum breaking load was found as the result of 1,000 single thread tests to be 4·7 oz. The graph (Fig. 3) shows that the maximum yarn tension reached 4·7 oz. when the winding speed was 405 yards/minute. This is equivalent to a spindle speed of 1,160 revolutions/minute when the maximum diameter of the warper's bobbin is 4 inches.

The tension in the yarn during twist winding is due to (1) the frictional drag imposed by the flannel board, guides, and clearer, (2) the ballooning of the yarn as it comes from the nose of the ring tube. It was proved experimentally that the frictional drag imposed by the flannel board, guides, and clearer, remained constant as the winding speed increased. This was established by unwinding yarn from a revolving supply bobbin the diameter of which was kept practically constant, being allowed to vary only from $3\frac{10}{24}$ in. to $3\frac{6}{24}$ in. The frictional drag as registered by the tension recorder then remained constant while the yarn speed was increased from 55 to 540 yards/minute.*

The yarn tension in winding is due (1) to the constant drag imposed by the flannel board, etc. and (2) to the drag imposed by the ballooning of the yarn as it leaves the nose of the ring tube; this drag increases as the winding speed increases. During the experiment the maximum yarn tension due to the friction drag plus the balloon drag increased from 3·9 oz. to 8 oz. as the yarn speed increased from 254 to 624 yards/minute; the increase being due to the ballooning of the thread. As the yarn speed increased from 254 to 324 yards/minute the maximum tension due to the ballooning of the yarn only increased from 3·85 oz. to 4 oz., an increase of 0·15 oz. Below 254 yards/minute the increase in the value of the tension due to the ballooning of the thread is negligible (graph of maximum is almost a straight line). Therefore in order that the tension due to the ballooning of the yarn shall attain a value of 4·7 oz. the yarn speed must increase to approximately 645 yards/minute. The 34's yarn used in the course of the experiments could thus be unwound from the nose of a cop-built ring-tube at a winding speed of 645 yards/minute without breakage of the thread due to yarn tension in winding. With the upright spindle winding machine, such a high speed is not possible because it is necessary to put additional tension in the yarn by means of a flannel board, or some other form of tensioning device which applies frictional drag to the yarn, in order to build a bobbin which is sufficiently solid for practical use. If "ballooning" only was relied on there would be very little tension at the bare bobbin, although probably sufficient at the full bobbin.

1 (b) Side Winding

When yarn is unwound from the side of a revolving ring bobbin placed upon a spindle, the tension in the yarn is due to two causes (1) the force required to overcome the friction of the bobbin and spindle, (2) the accelerating force for the bobbin and spindle. These forces were measured experimentally by placing a ring bobbin on a spindle at a height of 6 ft. and suspending from it a weight by means of a cord. The cord was wound upon the bobbin and the weight increased until it was sufficient to cause the bobbin and spindle to revolve and to cause the weight to fall. The following results were obtained—

Weight of full tube and spindle (W_1) ... ... = 6·25 oz.
Height of fall (H) of weight ... ... = 6 ft.
Weight W ... ... = 2·125 oz.
Time for weight to fall 6 ft. ... ... = 1·5 secs.
Average velocity ... · ... ... = 4 ft /sec.
Number of revolutions of bobbin and spindle (30 revolutions during fall of W and 18 revolutions after W reached the floor) ... ... = 48

(*a*) The maximum velocity (v) of weight W = 2 × average velocity = 8 ft./sec. The kinetic energy in the weight W when it reaches the floor=

$$\frac{Wv^2}{2g} = \frac{2\cdot125}{16} \times \frac{64}{2 \times 32\cdot2} = 0\cdot132 \text{ ft. lb.}$$

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* Under most circumstances friction is independent of speed, but Morrow in a paper published in the *Journal of the Textile Institute*, Vol. XXII, No. 9 (1931), showed that the coefficient of friction of cotton yarn and polished steel, although 0·25 at a low velocity, increased as the velocity increased. The increase was considerable at low velocities but was small (from 0·35 to 0·42) as the yarn speed increased from about 60 to 600 yards/minute.

(*b*) The energy expected in turning the ring bobbin and spindle = W × H − K.E. in W when it reaches the floor=

$$\frac{2\cdot125}{16} \times 6 - 0\cdot132 = 0\cdot666 \text{ ft. lb.}$$

(*c*) The kinetic energy in bobbin and spindle when the weight reaches the floor = (WH − K.E in W) − the energy spent in overcoming friction during the fall of W $= 0\cdot666 - 0\cdot666 \times \frac{30}{48} = 0\cdot25$ ft. lb.

The average speed of the bobbin = 30 revolutions in 1·5 secs.= 20 revs./sec., therefore the maximum speed (n) = 2 × 20 = 40 revs./sec. The kinetic energy of the bobbin and spindle when the weight touches the floor = 0·25 ft. lb.

$$= \frac{W_1 v^2}{2g} = \frac{W_1\,(2\pi k n)^2}{2g}$$

where $v = 2\pi k n$ and k = the radius of gyration. Therefore

$$0\cdot25 = \frac{6\cdot25}{16} \times \frac{(2\pi k\ 40)^2}{2 \times 32\cdot2} = 383\cdot2\ k^2. \text{ Thus } k = 0\cdot0006525.$$

$$\text{The moment of inertia (I)} = \frac{W_1 k^2}{g} = \frac{6\cdot25}{16} \times \frac{0\cdot0006525}{32\cdot2} = 0\cdot000007914.$$

The velocity of the ring bobbin and spindle increases as the yarn moves from the shoulder to the nose of the ring bobbin, the number of coils unwound being 18 coils or 60·5 in. of yarn. The yarn speed when winding upon a warper's bobbin of 4 in. diameter at a spindle speed of 750 r.p.m $= \frac{750 \times \pi 4 \text{ in.}}{36} = 262$ yds./min.

$$\text{The time for the traverse} = \frac{60 \times 60\cdot5}{36 \times 262} = 0\cdot38 \text{ sec.}$$

The time for each coil is proportionate to its length, therefore the time for the last coil =

$$\frac{0\cdot38 \times \text{length of last coil}}{\text{Length of 18 coils}} = 0\cdot38 \times \frac{2\cdot55 \text{ in.}}{60\cdot5 \text{ in.}} = 0\cdot016 \text{ sec.}$$

The change of speed of the ring bobbin during the unwinding of the last coil was obtained from a graph showing how the speed of the ring bobbin changes as the yarn is unwound and moves from the largest to the smallest diameter. The change of speed during the unwinding of the last coil was found to be 1·9 revs./sec. in 0·016 sec., therefore the average acceleration during the last coil =

$$\frac{1\cdot9}{0\cdot016} \text{ revs./sec./sec.} = 1\cdot9 \times \frac{6\cdot2832}{0\cdot016} = 746\cdot3 \text{ radians/sec./sec.}$$

The yarn tension must overcome (1) the friction of the spindle and bobbin and (2) the accelerating force for bobbin and spindle (greatest at nose of bobbin). The friction of the spindle and bobbin =

$$\frac{\text{energy spent to overcome friction per revolution in test}=}{\text{circumference of bobbin}}$$

$$\frac{0\cdot666}{48 \times 0\cdot208} = 0\cdot0667 \text{ lb.} = 1\cdot07 \text{ oz.}$$

The accelerating moment for bobbin and spindle = moment of inertia × angular acceleration = 0·000007914 × 746·3 = 0·0059 lb. Therefore the accelerating force=

$$\frac{0\cdot0059}{\text{mean radius of bobbin for last coil in feet}} = \frac{0\cdot0059}{0\cdot033} = 2\cdot86 \text{ oz.}$$

Therefore the maximum yarn tension when winding from the full ring bobbin on to a warper's bobbin of 4 in. diameter at a spindle speed of 750 revs./min. (262 yds./min.) = 1·07 + 2·86 = 3·93 oz.

At 500 r.p m. the change of speed of the ring bobbin in unwinding the last coil $= 1{\cdot}9 \times \frac{500}{750}$ revs./sec. in 0·016 sec. $\times \frac{750}{500}$ sec. $= \frac{1{\cdot}9 \times 500 \times 500 \times 6{\cdot}2832}{750 \times 0{\cdot}016 \times 750}$ $= 331{\cdot}6$ radians/sec /sec. Therefore the accelerating moment for bobbin and spindle $= 0{\cdot}000007914 \times 331{\cdot}6$ lb. and the accelerating force=

$$\frac{0{\cdot}000007914 \times 331{\cdot}6 \times 16}{0{\cdot}033} = 1{\cdot}27 \text{ oz.}$$

Therefore the maximum yarn tension when winding from the full ring bobbin on to a warper's bobbin of 4 in. diameter at a spindle speed of 500 r.p.m. $= 1{\cdot}07 + 1{\cdot}27 = 2{\cdot}34$ oz.

The following table shows the maximum yarn tension at various spindle speeds (warper's bobbin spindle), as the result of calculations made in the above manner.

Table II

Spindle speed (warper's bobbin spindle)	Maximum winding speed yds./min. when winding on a warper's bobbin of 4 in. diameter	Maximum yarn tension (ozs.)
500	174·5	2·34
750	261·75	3·93
1000	349	6·16
1500	523·5	11·45

The spindle speed must therefore be kept low or the yarn will be broken by the tension in it. A 34's yarn (22·6 turns/1 inch) with a mean breaking load of 6·75 oz. and a minimum breaking load of 3·7 oz. would require to be wound at a spindle speed of not more than about 720 r.p m if we desired to avoid breakages on account of the tension placed in the yarn as the result of side winding from a cop-built ring-bobbin.

In some cases warp yarn is unwound from the side of a roving-built ring-bobbin which during winding is (1) placed on a spindle, or (2) held in some form of spool holder. When a roving-built bobbin is placed on a spindle, the tension in the yarn is equal to the force required to overcome the friction at the spindle bearing and cause the bobbin and spindle to revolve. This force was found by experiment to be 0·061 oz. for a full bobbin and 0·1 oz. for an empty bobbin (weight of bobbin and spindle 6·25 oz. Diameter of bobbin—maximum 1·4 in., minimum 0·8 in.), an increase of 0·039 oz The winding speed does not affect the yarn tension since all tension is due to friction In order to place a greater tension in the yarn, frictional drag is often placed on the wharfe of the spindle by means of a cord, or in some cases each wharfe has a small tensioning device attached to it consisting of a small weight attached to a loop of cord round the spindle wharfe. All tension in the yarn, however, depends upon frictional drag and therefore the only increase in tension is the increase of 0·039 oz. due to the alteration in radius and weight of the ring tube as the yarn is unwound from it.

When a roving-built bobbin is held in a spool holder, the yarn is unwound from the side of the bobbin which during winding rests upon a polished steel bedplate. Two tension wires, one on each side, also hold the spool lightly. The yarn tension during winding must be such that $W_1r = uWr + uFr$, where W_1 = the yarn tension; r = the radius of the spool; W = the weight of the ring spool, and F = the pressure exerted by the tension wires. By experiment the coefficient of friction (u) between cotton and polished steel was found to be 0·2509. $W_1r = uWr + uFr$, therefore $W_1 = u\,(W + F)$. As the tube empties the value of W + F decreases since the weight W changes from 1·75 oz. to 0·75 oz. and the force exerted by the tension wires is also lower. The yarn tension due to the weight of the spool $= uW = 1{\cdot}75 \times 0{\cdot}2509 = 0{\cdot}439$ oz. when the spool is full, and $0{\cdot}75 \times 0{\cdot}2509 = 0{\cdot}188$ oz. when the spool is empty. The value of the yarn tension (W_1) decreases therefore as the ring tube becomes empty and being due to frictional drag upon the spool does not increase (or only increases to a small degree) as the winding speed increases.

THE EFFECT OF WARP WINDING UPON THE BREAKING LOAD AND EXTENSION OF YARN

In order to find the effect of winding upon the breaking load and extension of yarn a 34's ring twist was tested before and after winding. To ensure an accurate comparison and to avoid errors due to the irregularity of the material 1,000 single thread tests were made in each case. In testing the yarn before winding, 50 single thread tests were made from each of 20 ring bobbins. The tests made after the yarn had been wound represent 1,000 tests from a warper's bobbin, 100 single thread tests being taken at approximately 10 equal intervals throughout the bobbin. The Baer single thread tester was used for making the tests, and after testing the probable error of the results was calculated and comparisons of the breaking loads and extensions were made.

The following results were obtained in the case of yarn unwound from the nose of the ring bobbin, tensioned by a flannel-covered board and passed through a clearer (setting $\frac{14\text{ in.}}{1{,}000}$). The winding machine used was the vertical spindle winder.

Table III

Yarn	Weight of yarn placed on warper's bobbin (oz)	Mean breaking load (oz.)	Mean extension (%)
A—34's twist (24·4turns/in) ...	- -	7·55 ± 0·018	5·55 ± 0·015
B—Ditto (wound at 500 r.p.m.)	15½	7·58 ± 0·017	4·40 ± 0·017
C—Ditto (wound at 2,000 r.p m.)	16	7·92 ± 0·018	4·17 ± 0·014
D—Ditto (wound at 2,000 r p m. under heavy drag)	20	8·27 ± 0·02	4·91 ± 0·018

These results show no significant change in breaking load after winding at 500 r.p.m. but a small yet significant increase in the case of the yarns wound at 2,000 r.p.m. There is, however, a significant decrease in the % extension after winding in every case.

Very similar results were obtained with another 34's ring twist when the yarn was unwound from the side of a ring tube placed upon a revolving spindle, the yarn being cleaned by a brush before passing through the clearer.

Table IV

Yarn	Weight of yarn placed on warper's bobbin (oz)	Mean breaking load (oz.)	Mean extension (%)
E—34's twist (22·6 turns/in.)...	—	6·75 ± 0·017	6·38 ± 0·022
F—Ditto (after side winding at 500 r.p.m.)	15½	6·97 ± 0·015	4·21 ± 0·017
G—Ditto (after side winding at 750 r.p.m.)	15¾	6·95 ±0·028	4·16 ± 0·016

In each case these tests show a small yet insignificant increase in the load required to break the yarn and in addition show a significant decrease in extension after winding.

In warp winding by means of the vertical-spindle winding machine it is necessary to place considerable tension in the yarn in order to build a warper's bobbin sufficiently solid for practical use. The tension thus placed in the yarn does not lower the breaking load, but it nevertheless injures the yarn since it results in a loss in extension. It would appear advisable, therefore, to put as little tension as possible in the yarn during winding and to build bobbins as soft as is consistent with their satisfactory use in warping. In the case of side winding from cop-built ring bobbins, this means that the spindle speed must be low since an increase in speed results in a rapidly increasing value for the accelerating force for the ring bobbin and spindle, and therefore increasing tension in the yarn. In nose winding a low speed is not necessary since the amount of tension in the yarn is regulated by the tensioning devices which impose frictional drag, and the value of the tension thus placed in the yarn plus the tension due to the ballooning of the thread, can be regulated and made suitable for the counts of yarn and the spindle speed of the machine. In this case other factors determine the maximum speed at which the spindles may be run, piecing up and the restarting of the bobbins become difficult for example at spindle speeds above 1,000 r.p.m.

In both side winding and nose winding at the vertical-spindle winder, loss in extension appears to be inevitable, since when the solidarity of the warper's bobbin depends upon the tension in the yarn, this tension, if a firm bobbin be built, is of such a value as to cause a loss in extension after winding.

In winding cheeses or cones the yarn package is driven by surface contact with a driving drum and it is not necessary to rely entirely upon yarn tension in order to produce a firmly built package; hence injury to the yarn may be avoided. In cone winding it is usual to obtain a firm build partly as the result of pressure between the cone and its driving drum, and partly as the result of tension in the yarn resulting from the use of some form of tensioning device which imposes frictional drag. It is, I believe, impossible at present to produce a firmly-built cone as the result of pressure only; a certain amount of tension in the yarn is also necessary. It would, however, appear desirable to impose as little tension as possible in the yarn itself and to rely as far as possible upon pressure between the cone and its driving drum to give a firmly-built yarn package.

Warp yarn may be wound at high speed, without injury, if the tension in the yarn can be kept low For example an 18's ring twist wound at 1,200 yds./min. from roving-built ring bobbins on to a cheese gave the following results when tested before and after winding. The figures are in each case the mean of 500 single thread tests made by means of a Baer single thread testing machine.

Table V

Yarn	Mean breaking load (oz.)	Mean extension (%)
18's twist	12·18 ± 0·042	5·84 ± 0·024
Ditto (after winding at 1,200 yds./min.) ...	12·29 ± 0·066	6·17 ± 0·023

This yarn was wound from the nose of the ring tubes on to the cheese by means of a Barber Colman automatic spooling machine. The cheese, which was built up on a ball-bearing core, was driven by frictional contact with a driving drum, a firm cheese being obtained as the result of pressure between the cheese and its driving drum plus the tension in the yarn due to the ballooning of the thread as it left the nose of the ring bobbin. The breaking load before and after winding showed no significant change nor was the yarn extension under load impaired.

YARN BREAKAGES DURING WINDING

The number of breakages during winding depends mainly upon (*a*) the regularity of the yarn, and (*b*) the provision of satisfactory working conditions. Tests made when winding a 34's twist at the vertical spindle winder from the nose of cop-built ring tubes showed that the number of breakages was approximately the same at spindle speeds of 500, 750, and 2,000 r.p.m. if the drag imposed by the flannel-covered drag board was adjusted to give the same weight of yarn per warper's bobbin in each case. The number of breakages varied, however, according to the setting of the clearer. When the clearer setting was 2 × the calculated diameter of the yarn, there was on the average one yarn breakage to every two ring tubes wound. With a wider setting the number decreased. Nearly all the breakages were due to (*a*) thick places in the yarn which were unable to pass the clearer, (*b*) seed particles embedded in the yarn which resulted in yarn breakage at the clearer, (*c*) the presence of loose fibres which gradually accumulated on the flannel-covered drag board and near the clearer. These loose fibres were at times picked up by the yarn and carried forward to the clearer. Many of the bunches of loose fibres thus picked up passed through the clearer and were carried forward on to the bobbin, others stuck in the clearer and resulted in breakage of the yarn.

Fewer breakages (one to every six ring tubes) were observed when winding the same yarn from the side of cop-built ring tubes carried upon a revolving spindle. The number of breakages, however, was the same at 750 r.p.m. as at 500 r.p.m. It was observed that all breakages were due to thick places which resulted in yarn breakage at the clearer, and that the reduction in the number of breakages in side winding as compared with nose winding was due to the fact that a cleaner yarn was being presented to the clearer. As the supply-bobbin revolved many loose fibres and seed particles were freed from the yarn as the result of centrifugal force, and the brush through which the yarn passed before arriving at the clearer further assisted in the cleaning of the yarn.

It was found possible to reduce the breakages in nose winding to approximately the same number as in side winding when great attention was paid to the clearing away of all loose fibres and seed particles freed from the yarn by the flannel-covered drag board. Such clean working conditions are, however, difficult to attain in the mill when the yarn has to be tensioned by means of any type of tensioning device which applies frictional drag. The application of frictional drag always results in an accumulation of loose fibres at the tensioning device, and these must be removed at frequent intervals by the winder (or better still by some automatic cleaning device) or they will again be picked up by the yarn, in which case they very often cause yarn breakages.

A small number of breakages are due to badly built bobbins or to seed particles on the chase of the ring bobbin upon which the yarn catches as the coils are being taken from the nose of the bobbin. In the latter case a high winding speed and the consequent formation of a larger "balloon" as the yarn leaves the bobbin results in a reduction in the number of breakages.

Under satisfactory working conditions the number of breakages in both side winding and nose winding are approximately equal and depend almost entirely upon the regularity of the yarn and the setting of the clearer. Adjustable clearers are frequently fitted but it is doubtful whether they are necessary for counts of 30's–50's, although probably desirable for coarser counts. The clearer setting is usually much greater than the yarn diameter, since if the clearer be set to be only slightly wider than the calculated diameter, the variation in diameter in the average yarn is such that excessive breakages will occur. For example, the calculated diameter of 34's twist $= \sqrt{34 \times 840}$ less 10% $= \frac{6{\cdot}5 \text{ in.}}{1000}$ approximately. With a clearer setting of $\frac{7 \text{ in.}}{1000}$ yarn breakages averaged 1 per 192 yards. In order to wind the yarn without an excessive number of breakages the clearer was set so that a winder's knot would pass through. The setting was then $\frac{14 \text{ in.}}{1000}$ approximately 2 × the calculated yarn diameter. With this setting the yarn was found to be cleared of all slubs and seed particles which would have been noticeable if allowed to get into the cloth and the number of breakages was thus reduced to 1 per 9,200 yards (one to every six ring tubes). The breakages were due to thick places or to seed particles embedded in the yarn, these thick places or seed particles being in every case so large that a much wider clearer setting would have resulted in breakage of the thread.

As the counts of yarn vary from 30's to 50's the calculated diameter ranges from $\frac{7 \text{ in.}}{1000}$ to $\frac{5{\cdot}5 \text{ in.}}{1000}$. On account of the small difference in the diameter of yarns within this range it is suggested that there is no object to be gained by adjusting the clearer for yarns within this range of counts, since a clearer setting of $\frac{14 \text{ in.}}{1000}$ would undoubtedly remove the slubs in these yarns. As the counts vary from 10's to 30's the calculated yarn diameters vary from $\frac{12 \text{ in.}}{1000}$ to $\frac{7 \text{ in.}}{1000}$. For this range of counts adjustable clearers are probably desirable. Adjustable clearers are thus useful in machines to be used for coarse counts or for a very wide range of counts, but for yarns of medium count they appear to be unnecessary.

The main object of winding is to build a yarn package of large size in order to reduce the number of stoppages in warping or other subsequent processes for which the yarn may be used. It is often claimed, however, that the quality of the yarn is improved as the result of winding, on the assumption that during this process thick places and weak places are eliminated and the yarn is cleared of loose fibre. It is true that the use of a clearer or slub-catcher results in the elimination of undesirable thick places and the removal of some loose fibre, but most tensioning and cleaning devices which impart frictional drag have a rubbing or scraping action and actually result in the formation of outstanding fibre as the yarn passes over or through them. Furthermore if the tension placed in the yarn by such devices is sufficiently great to result in the breakage of weak places the yarn is injured. Loading a yarn does not result in any reduction in its breaking load, but it nevertheless injures it since it reduces its extensibility. The extent of the loss is dependent upon the yarn tension as the result of loading and increases as the tension in the yarn is increased. In winding, therefore, it is desirable to impart to the yarn the minimum tension which will result in the building of a sufficiently firm yarn package and to confine attempts to improve the quality to the removal of thick places. It should be the task of the spinning department to deliver yarn of the type and quality desired, and it should not be necessary for the winding department to increase its costs in an attempt to improve the quality of the material. Improvement in yarn quality could in all probability be obtained at a lower cost in the spinning department than in the winding department Nevertheless it is impossible in spinning to eliminate thick places such as the slubs which result from piecings, hence the employment of a clearer or slub catcher is desirable at the winding frame, but attempts to improve the yarn quality should be confined to the removal of thick places which would cause yarn breakages in subsequent processes, or would look unsightly if allowed to get into the cloth.

SOME DEVELOPMENTS IN MACHINERY USED FOR WOVEN SMALLWARES

By W. HOLT

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The term Woven Smallwares includes a large number of fabrics many of which are used for special purposes and are of special construction. It is my intention to deal with the machinery for the production of Tapes, Webbings, Ribbons, and Labels. Tapes are generally understood to be of a plain weave. Webbings are usually of a twill weave. Ribbons of silk or artificial silk are of a more varied texture, whilst labels are generally weft figure on a plain or Satin ground.

The manufacture of tape was introduced into England from Holland about the middle of the 18th century, the object being to provide the inhabitants of certain villages in Staffordshire with work. It is recorded that two Dutchmen, skilled in the craft of weaving, were induced to come over and instruct the villagers in the craft. It would also appear that they instructed the village carpenter and blacksmith in the art of loom building. The looms were made mostly of wood, the frames often being of oak of substantial section. They were, of course, hand looms and had fly shuttles.

With the development of mechanical knowledge the construction of the looms was improved mechanically, but there are still a number of wood frame looms in work and a large number of tape looms still employ fly shuttles.

When considering the machinery used in smallware manufacture one sees a certain number of machines which are common to the textile trade, for example, hank to bobbin winding. Other machines are modifications of ordinary textile machines, whilst a large number are specially built to suit special conditions

Owing to the comparative smallness of this part of the textile industry, the building of the special machines required did not appear to be attractive to textile machinists and so we find some of the larger mills equipped to build their own machines and looms. This naturally encouraged development along specialised lines and so long as the construction of the machine was simple it was fairly satisfactory, but now we find that manufacturers require better built looms etc , which machinists are laying themselves out to supply.

Preparation

Winding machines to wind from hank are of the usual type. A few years ago these were almost entirely from hank to double-ended bobbins, now one finds the latest type of cheese winders and if the supply is twiner cop or doubler bobbin, bottle bobbin machines or cone winding machines are used.

Warping

Owing to the small number of ends in the warp, a number of warps are often made on one machine in the form of cross-wound cheeses; the supply being double-ended bobbins, cheeses, bottle bobbins, or cones The older type of machine consisted of creel for double-ended bobbins, lease board, traverse motion, and leather-covered drums on which the cheese warps were built. There was no stop motion and no measuring motion. The warper was given the number of ends, count of yarn, and weight of warp. When she judged the size to be about right she lifted out the warp, weighed it and if right, put in an end and end lease which she picked with her fingers. This was a very slow proceeding and we now find machines equipped with stop motions for broken ends, measuring motions, and leasing reeds.

One of the latest types of warping machine has a creel fitted to take bottle bobbins with tension for each thread, and a modified beaming machine headstock with measuring roller, stop motion, leasing reed, and brake motion for quick stopping. The yarn is taken from the lease reed a distance of four or five feet, to allow a gradual condensing of the threads to a tape and also to ensure stopping before a broken end is wound on to the warp. The winding-on portion consists

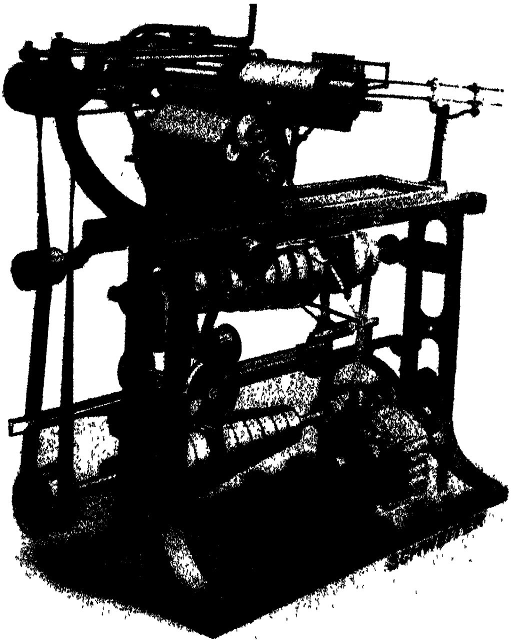

FIG. 1

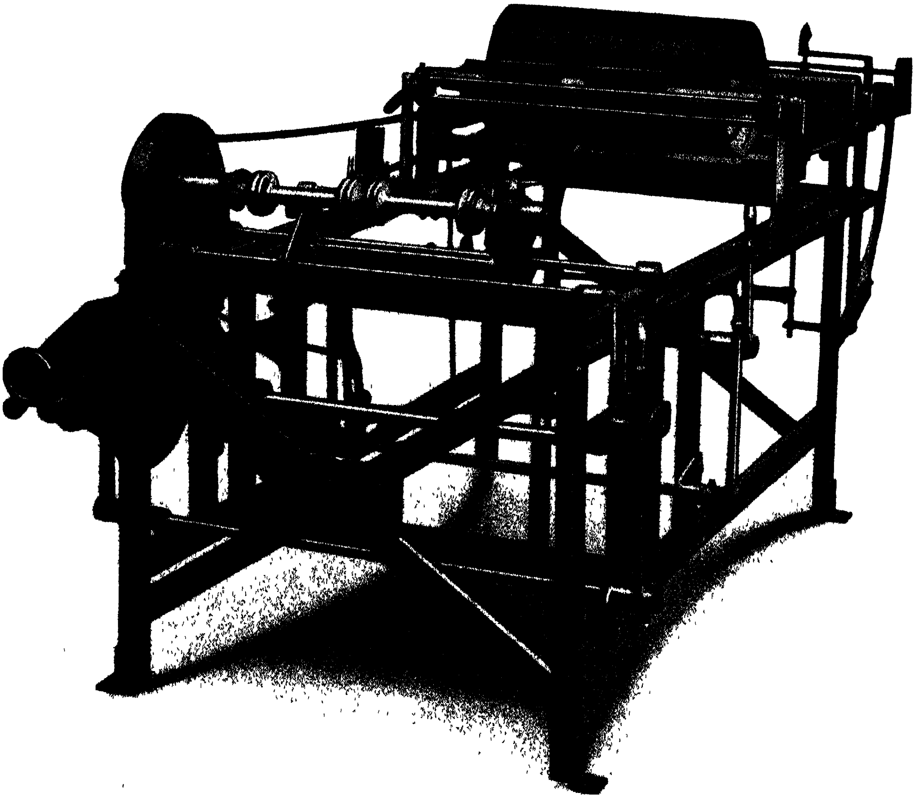

Fig. 2

of six to twelve drums, each for a separate cheese, and a quick-traverse motion. Such a machine making eight warps of 2/28's cotton and with not more than 400 ends in creel can easily produce 2,200 lb. of warps per week. The labour required being one girl with assistance during creeling and doffing.

In the fancy smallware trade, one still sees hand warping machines in which the warper winds on the warp by turning a handle with one hand and traverses the threads with the other hand.

With the introduction of artificial silk the comparatively crude methods used for cotton and linen yarns were found unsuitable and precision machines have been introduced. For winding, the usual types of machines are used with the latest mechanism for avoiding strain. Warping is done in cheese form on machines as shown in Fig. 1 with stop motion, measuring motion, and variable speed arrangements to maintain a constant winding on speed. One or two warps are run on at once according to the number of ends, and up to 6,000 yards are put on one warp. Other machines as Fig. 2 make a warp on a small flanged bobbin or beam in the same way as a beam in the broad trade. Here again we have stop motion, measuring motion and variable speed motion. The yarn is wound on in sheet form and sometimes a slight traverse is given to prevent building up against the flanges.

Weft

The weft yarns have to be wound on to small bobbins or quills to fit the small shuttles. Some quills have flanges whilst others are tubes only. A few years ago it was not uncommon to see the flanged quills wound by hand on a machine resembling the old spinning wheel. The quill was pushed on to a tapered spindle driven by a tape from a large wood handwheel and the yarn was traversed by hand. A skilful winder could make remarkably good quills but production was low.

We then find machines equipped with a number of narrow wood drums covered with leather and a traverse rail driven from a heart cam, one winder would attend to forty or fifty ends and some of the machines were made to throw the quill out of contact with the drum on reaching a certain size. Here again the skill of the winder played no little part in the making of good quills.

The friction drive was satisfactory for coarse yarns but not so good for fine yarns and so we find machines in which the quill is driven by being gripped at the ends and, to allow of yarns of different count being wound satisfactorily, small adjustments to individual traverses are possible We also find an increasing number of cross-wound quills being wound on the precision type of machine. Some have straight ends but for fine yarns and artificial silk taper end cross-wound quills are preferable as there is less chance of the yarn dropping over the end. Cross-wound quills permit of a larger weft supply for a given size of shuttle and may be considered necessary for artificial silk. Their economic value for the cheap cotton tapes woven on fly shuttle looms is doubtful.

Looms

Smallware looms can be divided into two principal classes. (1) Multiple-piece looms having from four to eighty pieces according to width of loom, width of fabrics being made, and the ideas of the manufacturer. (2) Single or two-piece looms, each containing all the necessary mechanism and capable of running at high speeds.

In the first group, which is by far the larger, we have fly-shuttle looms with one row of fabrics. Rack and pinion looms with 1, 2, or 3 rows of fabrics, with straight or curved shuttles. Drop box or multi-tier looms with from two to six rows of shuttles to allow of using two to six colours of weft. Looms with tappet shedding for tapes and webs with the usual limitations of tappet shedding. Looms with dobbies and also jacquards

There are also a large number of special looms built to make special fabrics. For example, the loom for ladder tape which is used for Venetian blinds has four rows of shuttles, all moving together to make four superimposed tapes. Another special feature of this loom is the shedding mechanism by which some of the shafts can be positioned to weave with any one of the four rows of shuttles as required. The loom for weaving the well-known "Rufflette" curtain tape has two rows of shuttles, one of which makes the little pockets simultaneously with the main tape.

The disadvantage of these multiple-piece looms is, of course, the fact that production must stop on all the pieces whenever the loom stops, even though one piece only requires attention. Their efficiency is comparatively low, 66% being a good average. This has led to a gradual reduction in the size of looms, smaller looms, and more looms per weaver being considered better, from a production point of view, than large looms and one loom per weaver. The low capital cost per piece is considered an advantage by the advocates of large looms.

In the second class there are two types. The first has two pieces and was introduced some years ago by an English firm for weaving tapes and webs. It has been adopted by a few firms only. Mechanically it can be considered an improvement on the multi-piece looms then in use.

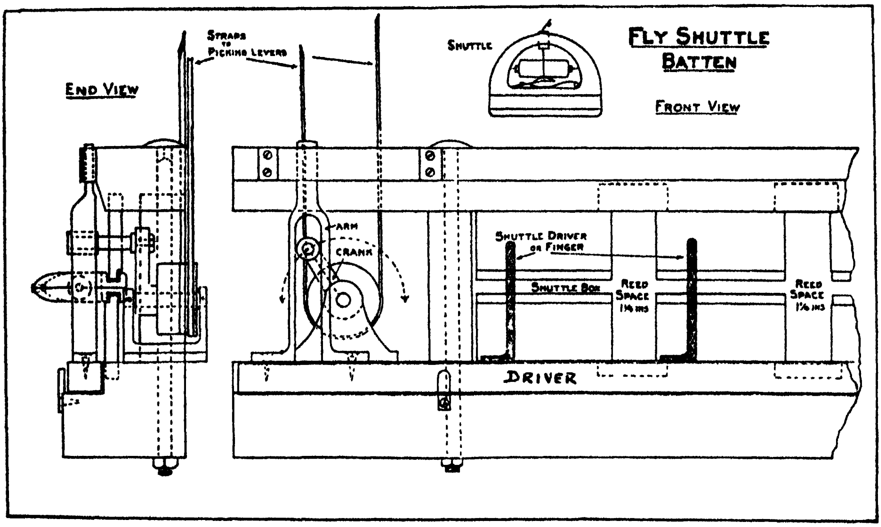

Fig. 3

More recently a Swiss firm has developed a single-piece loom which I believe was first made by an Englishman. This loom is being very successfully used for weaving narrow artificial silk ribbons or tapes up to ¾-in. wide and of weaves which can be produced on four shafts and four picks per repeat. It is so well made mechanically that it is possible to weave untwisted, unsized artificial silk of 150 denier at 700 picks per minute. When this is compared with a maximum 180 picks per minute of a multi-piece loom, which cannot satisfactorily weave 150 denier untwisted and unsized warp, then one realises how well this loom is designed and made.

Let us now consider the various motions of smallware looms to show how they have improved. First, the slay or batten as it is usually called. This is a very important part of the loom as upon its proper design and construction depends largely the efficiency of the loom. These battens sometimes carry as many as 160 shuttles for 80 pieces of two-weft fabric. The oldest and simplest type is the fly-shuttle batten, Fig. 3, for single-weft fabrics and used to-day very largely for tapes. This consists of a wood bed three or four inches square and often made of hardwood for strength. On this bed are mounted the shuttle boxes to the number of pieces to be made plus one. Wood pillars are fixed at intervals and these carry the top of the batten which serves the same purpose as the slay cap in a broad loom. This is usually of wood 3 or 4 in. square to assist in stiffening up the whole. Slots are cut out in top and bottom behind and between the shuttle boxes to carry the reeds. In front is a driver consisting of a piece of hard wood about 1½-in. square extending the full length of the batten. At one end a slotted arm is fitted which receives the bowl at the end of a crank mounted on the bed of the batten. A number of fingers or shuttle drivers are also fixed, one for each box. The crank is moved from left to right and then from right to left by means of tappets on the second motion shaft. This movement is transmitted to the drivers and so to the shuttles. The driver teeth can only move the length of a shuttle box but the shuttle has to move across the reed space and is thrown the last part of its movement, coming to rest in the next shuttle box against the next driver tooth. As there is no race board to support the shuttle when moving through the shed, it is necessary that it should be well supported in one box until it enters the next. To ensure good work it is advisable to have the shuttle boxes two and a half times the width of the reed space, although it is possible by skilful tackling to work with a box twice the length of the reed space.

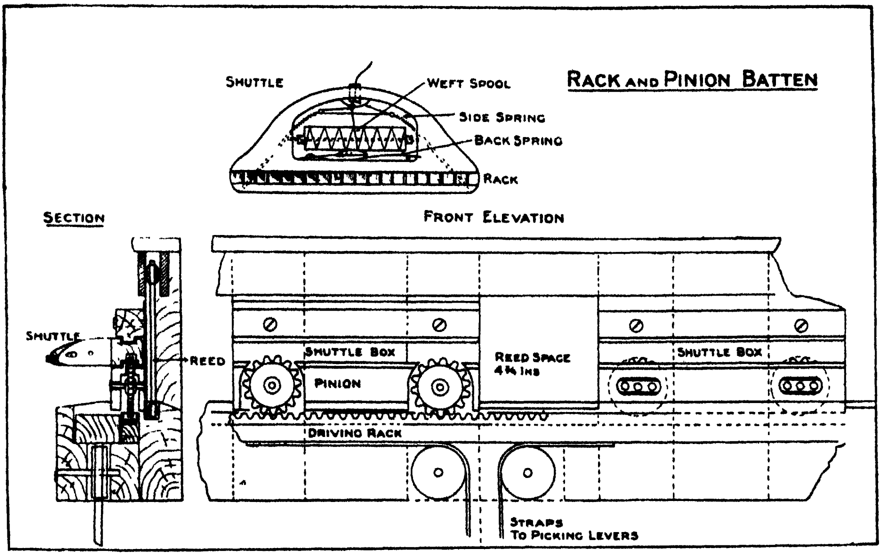

FIG 4

There does not appear to have been a satisfactory shuttle-checking device fitted to this type of batten, so that we find early attempts to propel the shuttle positively. One of the first of these is the Peg Shot in which the shuttles have two holes, one at each side. In place of the driver as used in the fly shuttle batten are two wood rails extending the full length of the batten. Each rail has a series of pegs coinciding with the holes in the shuttles, also a number of cut-out portions at the lower edge. These cut-out portions rest on a similar number of rollers fixed to the bed of the batten. There are two tappets on the second motion shaft each connected to a driver rail through treadles and straps. The action is as follows—Say the shuttles are at the left, one rail is in its highest position with its pegs in the holes on the left-hand side of the shuttles. The other rail is in its lowest position, the pegs being in a position to pass underneath the shed but coinciding with the holes on the right-hand side of the shuttles. Both rails move until the shuttles have moved half their traverse and then due to the shape and position of the cut-out portions they change places and the movement of the shuttles is completed. This is an improvement in the mechanical movement of the shuttles, but it does not appear to have been adopted except in certain sections of the trade.

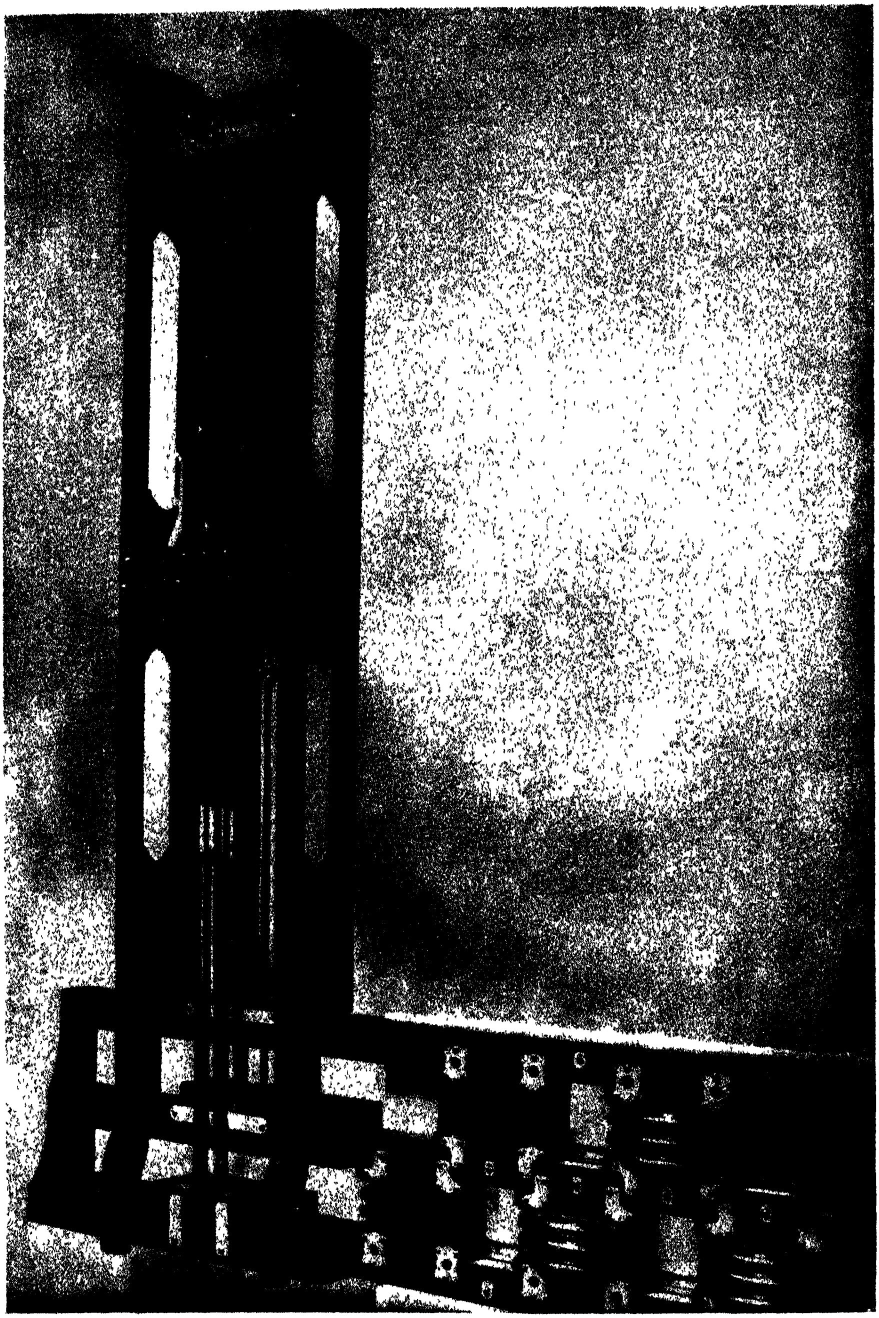

FIG. 5—3-Tier Mockspace Batten.

The next improvement in the propulsion of the shuttles is known as the rack-and-pinion batten, Fig. 4. In this each shuttle has a length of toothed rack inserted in the back. The shuttle boxes have two or more pinions which are large enough to make contact with the shuttle rack and also with a toothed rack which extends the full length of the batten and is placed in a groove in the bed of the batten immediately beneath the pinions. This long rack receives a movement equal to the length of the box plus the width of the reed space, first to the left and then to the right. Thus the shuttles are positively driven. The shuttles must be long enough for their racks to be in gear with two adjacent pinions and at least two-and-a-half times the width of the reed space, to ensure good working.

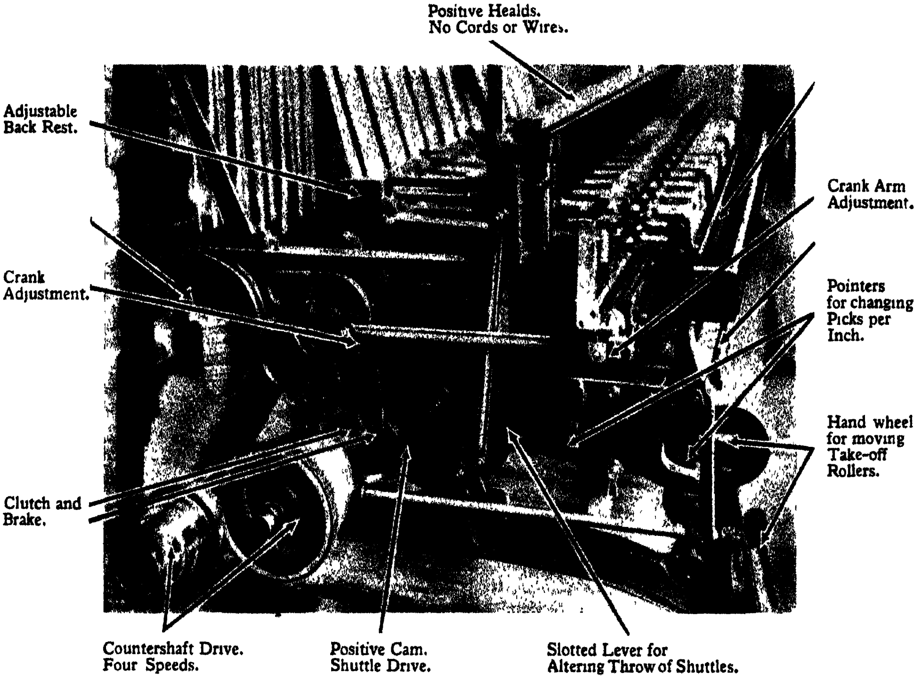
Positive Healds.
No Cords or Wires.
Adjustable Back Rest.
Crank Arm Adjustment.
Crank Adjustment.
Pointers for changing Picks per Inch.
Hand wheel for moving Take-off Rollers.
Clutch and Brake.
Countershaft Drive. Four Speeds.
Positive Cam. Shuttle Drive.
Slotted Lever for Altering Throw of Shuttles.

FIG. 6

The toothed racks are made chiefly of leather mounted on wood, but wood, fibre, and metal are being used. The pinions are made of bronze, fibre, or hide. With the improvement of gear-cutting machinery the construction of these racks and pinions has been very much improved.

This construction gives a good method of propelling the shuttles and various methods of moving the driving rack are adopted. Perhaps the earliest is the marionette, Fig. 5. This consists of a framework mounted on one end of the batten in which is a slide with a peg, worked up and down from a stud in the hand wheel of the loom. There are two rods connected together by a strap at the top for each row of shuttles, each having a hard wood catch near the bottom. From the bottom of each rod a strap connects up to the driving rack. The action of the marionette is as follows—the peg is at the bottom and also one of the catches. As the peg moves upwards it takes the catch with it and moves the driving rack from say right to left. The other rod and catch are pulled down and on the next upward movement of the peg this is taken up and the movement of the driving rack andshuttles is reversed. As this motion is obtained from a crank, the shuttle movement is practically harmonic. The weakness is in the catches which occasionally are missed by the ascending peg and then no shuttle movement takes place. An improvement on this method is to substitute properly-shaped cams, treadles, and straps for the marionette.

A further improvement is to use a positive cam. A bell crank lever from this cam works a vertical rack which engages with a long pinion directly geared to the driving rack. The long pinion is longer than the throw of the loom cranks so that there is a positive connection all the time. This motion is shown in Fig. 6.

The batten is usually swung from above. This enables a long sword to be used. The batten thus moves in an arc of a larger circle and the tilting of the shuttles is less, making it easier to get the shuttles through the shed without undue friction on the warp. Where battens are swung from below a number of levers are often used to give a straight movement to the batten but the large number of bearing points cause trouble when wear takes place.

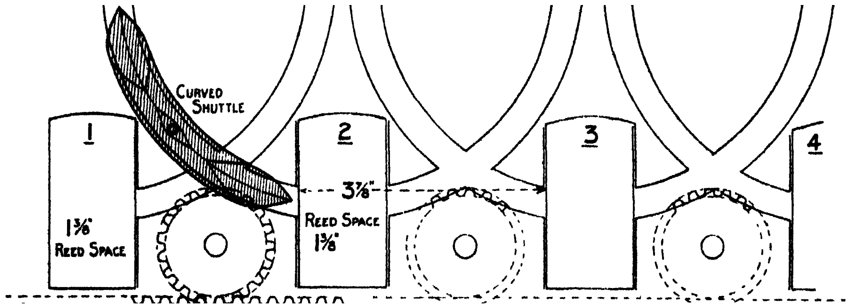

Fig. 7a.

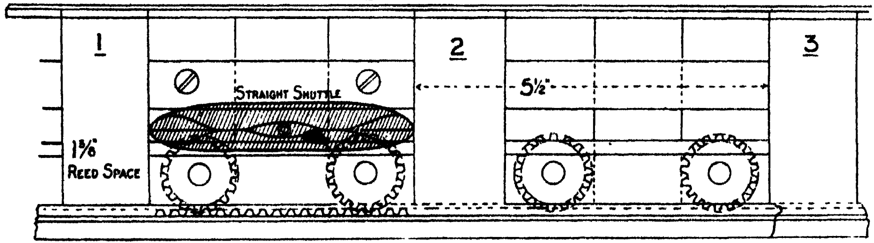

Fig. 7

This straight movement of the batten is very desirable and perhaps the best attempt to obtain this is seen in the Saurer multi-piece loom, Fig. 6, in which a long bearing is attached to the batten near each end. These work on slides fixed to each loom side. A perfectly straight movement is thus simply obtained, the long bearing being very effective in holding the batten upright at the time of beat-up.

As it is necessary for the shuttle boxes to be at least two-and-a-half times the width of the reed space it will be seen that the actual weaving space of the loom is less than one-third of width of the loom. Improvements have been made to increase the weaving space by having two or three rows of fabric made on one batten.

The two-row, or mock-space batten, is now very common and allows of approximately twice as many pieces being made in a loom of the same width. A second set of shuttles and shuttle boxes are placed above the first with the reed spaces over the centre of the bottom boxes. The driving rack is placed at the top.

In the three-row batten a further row of shuttles is added above the second, with the reed spaces equally divided. There are a number of mechanical difficulties in the construction and use of this three-row batten and not many are to be found in use.

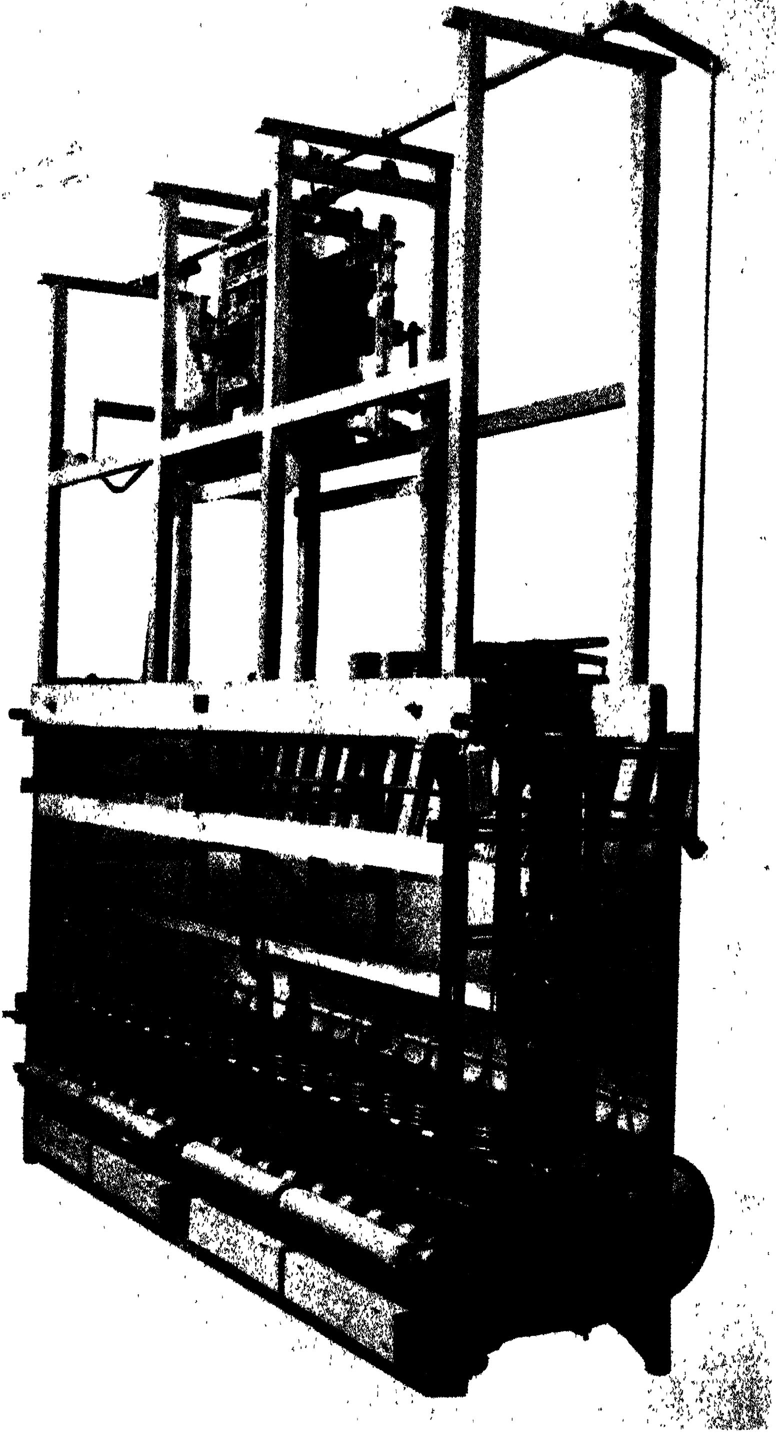

FIG. 8—Jacquard Smallware Loom with 4-Tier Batten.

Two and three-row battens are not so convenient as the single-row batten for the weaver, owing to the difficulty of dealing with the bottom row pieces. An attempt has been successfully made to retain the single row batten and at the same time increase the weaving space by the so-called circular batten. In this type of batten the shuttle races are not straight but form an arc of a circle as shown in Fig. 7a. The shuttles are shaped to fit and take up an inclined position when at rest in the boxes.

As shown in Fig. 7 we get approximately one-third more pieces than with straight shuttles in a loom of the same width, having the same width reed spaces and the same length of shuttles.

Multi-Tier Battens

When two or more kinds of weft are to be used in a fabric, a further modification of the batten is necessary, as seen in Fig. 8. The batten consists of two parts (*a*) the bed which carries the reeds, the pillars which support the top and the slides for the second part (*b*) which consists of the shuttles, shuttle boxes, and racks and pinions. This portion is mounted on the slides fixed to the bed and has a rise and fall movement sufficient to bring any row of shuttles into the weaving position. The shuttle drive is usually by means of a marionette. The lifting part has one or more extensions below, which pass through slots in the bed and terminate in rollers which run on a series of cam-shaped levers, one for each row of shuttles. As the batten swings backwards the lifting part runs on the cam levers and according to which lever is in working position the batten lifts to the required position. The selection of levers and therefore the position of the shuttle boxes is controlled by the Jacquard cards and as a slightly different timing from the shedding is necessary a small auxiliary Jacquard known as a "Mouse Trap" is used. This mechanism is shown in Fig. 11.

In order that only the required row of shuttles shall move, an addition is made to the marionette. A series of fingers are added, one for each catch. These fingers are moved by a series of projecting pieces on a frame fixed to the sword and are so arranged that the catch for the required row of shuttles is pressed forward to be taken up by the marionette peg, whilst springs hold back the other catches out of the way of the ascending peg. With this method of control it is not possible for the picking mechanism to get out of time with the shedding.

Although the weight of the sliding part of the batten is balanced, there is a considerable amount of wear on the rollers and cam levers. An improved method of lift is by properly-shaped cams, treadles, and overhead levers. Mechanism being provided with Jacquard control to select the desired cam for the lift required.

Shuttles

Shuttles for smallware looms are of various sizes and shapes to suit the fabric to be made. The simplest is the Fly Shuttle shown in Fig. 3. This is made of boxwood or other hard wood and is well polished. The back has grooves which fit the shuttle boxes and the front is bow shaped to take the weft bobbin or quill and the tension device. The weft unrolls from the side of the quill and passes through an eye at the front. Weft tension is obtained by a spring-loaded finger which presses on the back of the quill, the quill being mounted to run freely on a wire extending across the shuttle.

Shuttles for rack-and-pinion battens are somewhat similar to the above, but a length of toothed rack is inserted either in one of the grooves or in an additional groove at the back of the shuttle. A similar weft-tension device is fitted, with the addition of two spiral springs, one at each side inside the shuttle. The function of these side springs is to take up the slack weft when the shuttle begins to move and prevent snatching which is liable to occur when these springs are omitted. This snatching of the weft causes bad edges in the fabric. In some cases a special quill wire fitted with a recoil spring is used for the purpose of taking up the slack weft.

The shape of the bow front admits of much variation according to the ideas of the manufacturer. Some prefer a shuttle with taper ends to allow of easy entrance to and exit from the shed. Whilst others use a shuttle not so tapered to allow of a longer weft quill being used, with a correspondingly larger weft supply.

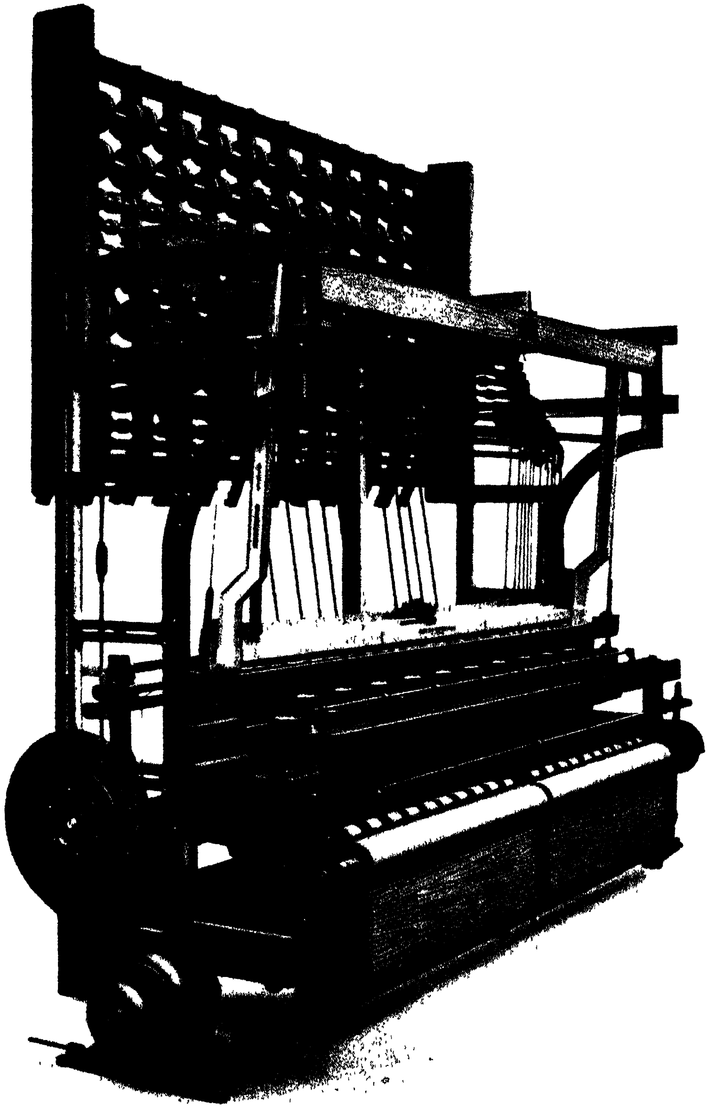

Fig. 9

Shedding

The shedding motion on fly shuttle looms is very simple. In the case of plain weave, two heald shafts are used, worked from tappets placed on the second motion shaft which has a speed of one-quarter of the crankshaft. Treadles have connections to a rocking beam placed on top of the loom, and pegs in this beam in turn are connected to levers fulcrumed on the front top rail of the loom; from the ends of these levers connections are made to the top of the heald shaft. The undermotion consists of cords, pulleys, and weights. This arrangement gives a jerky motion to the shafts and some looms are now being fitted with cross rod motions as in the Bradford broad loom which gives a smoother action to the healds, Fig. 9.

In one modern type of Swiss loom with tappet shedding positive cams are used with rigid connections to the shafts which are thereby controlled positively all the time.

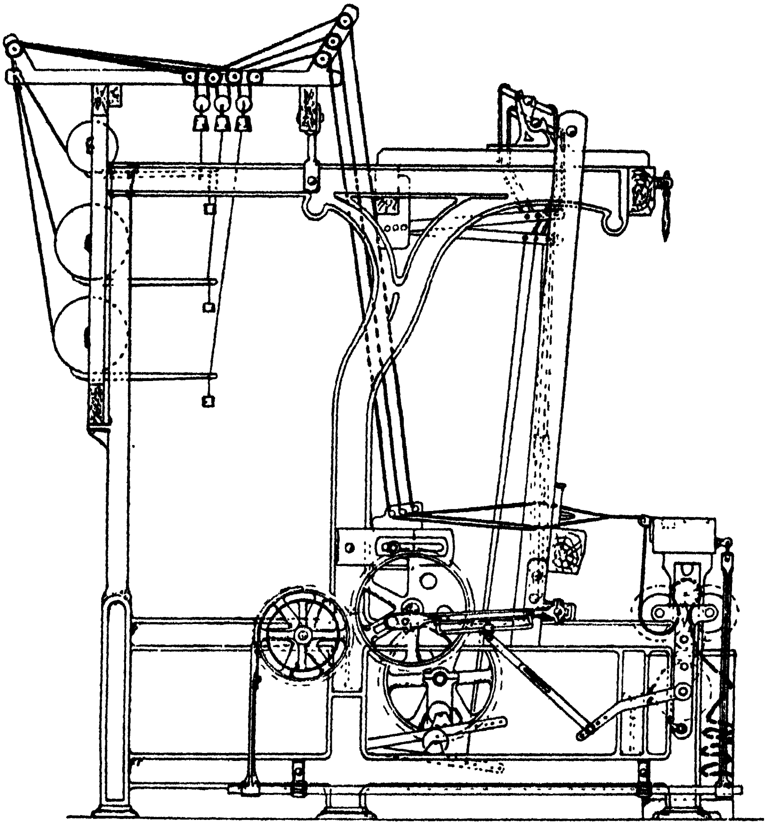

FIG. 10

Split shedding with specially-designed negative tappets is being applied to tappet looms by an English firm for closely-sett artificial silk ribbons such as Petershams. The tappets are designed to vary the speed of movement of the healds so that they pass the centre at different times, but all reach the top or bottom together and have the same period of dwell.

Dobby shedding motions are now being applied to these looms in increasing numbers, with, in some cases, astonishing increases in production. In some Swiss looms fitted with dobbies the crank is driven by eccentric wheels to give a longer period of dwell with a possible reduction in shuttle speed. This is a decided improvement when using artificial silk yarns.

Jacquards of the usual types are also used, single-lift single cylinder, double-lift single cylinder, and double-lift double cylinder machines are used.

In one recent loom made by an English firm a double-lift single cylinder machine is fitted, a cam lift is used and also a star wheel cylinder motion. The cylinder motion and cam lift are driven from an overhead shaft and no separate adjustment of the cylinder is necessary after retiming the Jacquard.

Warp Tension

Owing to the large number of pieces in a loom, warp tension presents a considerable problem. The warp beams are placed in a creel usually at the back of the loom and in the case of cross-wound warps the warps are led upwards to what is known as the top castle. This is placed on an extension at the top if the loom frame and consists of a number of wires on which are grooved wood pulleys. (As shown on Fig. 10.) The warps are passed over pulleys in the first and second row then down to a series of weighted pulleys, up again to the third row, forward to another row, and then down to the back rail of loom. In the simplest arrangement, the weaver goes to the back of loom, lets off sufficient warp to allow the weighted pulley to run nearly to the ground and then hooks up the warp to prevent further letting-off. As the fabric is woven the weighted pulley moves upward. This operation takes up a considerable portion of the weaver's time. An early improvement was to put a brake on the warp beam which was released as the weighted pulley moved upward, thus letting off a short length of warp. This saves the weaver a lot of work but the tension varies by the amount of extra weight in the brake lever. A further disadvantage of this system is the rolling

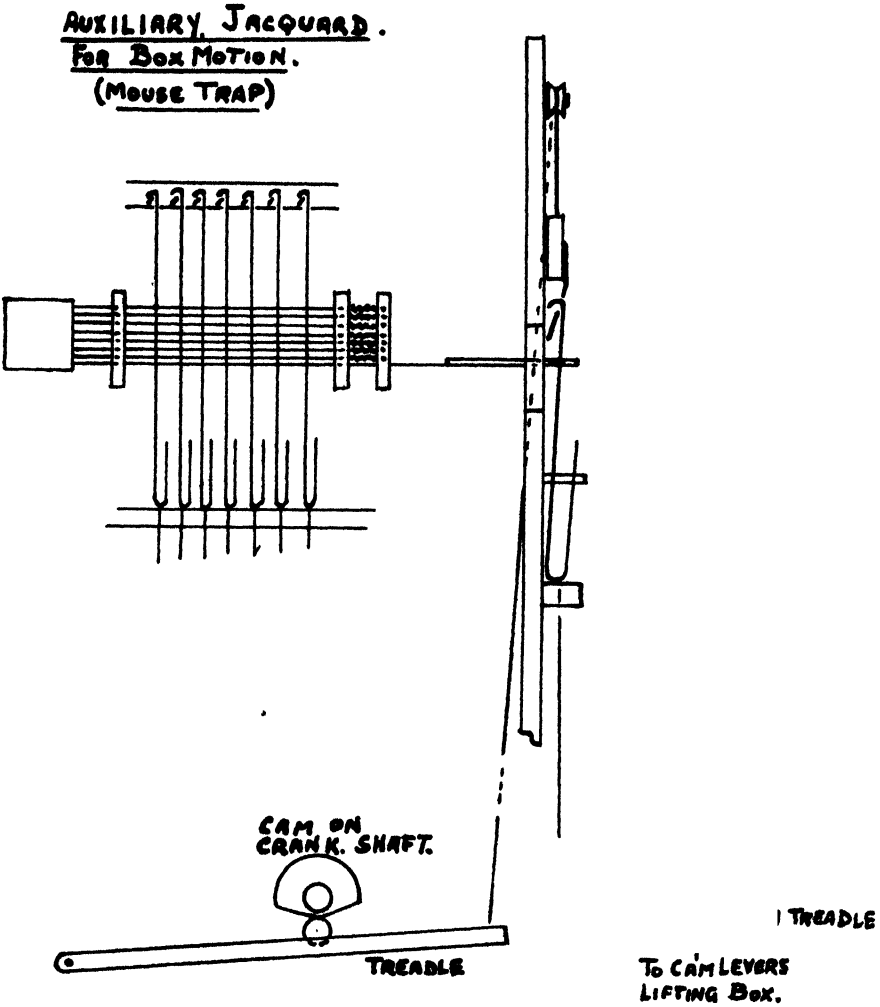

FIG. 11

of the warps by the rotary-grooved pulleys. This causes the warp to become twisted between the last pulley and the back reed and tight and slack ends are the result. With artificial silk warps this is a very serious matter and causes bright ends due to strained yarn. To obviate these troubles we find warps wound in sheet form on small beams used in creels where the warp passes straight from the beam to the back rail of the loom. The tension is applied by a brake cord which passed round a groove in the flange of the beam, one end is attached to the creel frame and the other to a weighted lever. As the beam weaves down, the tension must be reduced by moving the weight nearer to the fulcrum of the lever. This has the usual disadvantages of similar systems due to carelessness or bad judgment of the weavers.

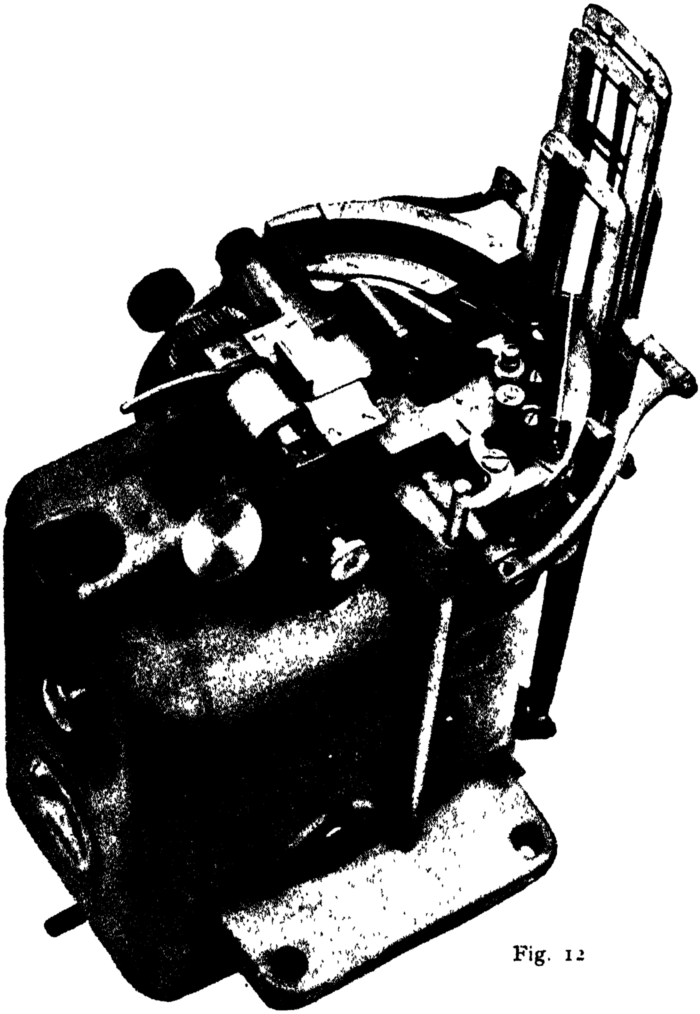

Fig. 12

In the Haywood loom a very good attempt has been made to improve the tensioning of the warp by making the tension of the warp threads regulate the let-off of the warp. This consists of a spring-loaded vibrating back-rest. Each piece has its own separate back-rest with a connection to the warp-brake lever. The warp beams are mounted towards the front of the loom and pass backwards to the back rest. As the warp is drawn forward this pulls the back rest forward and when it reaches a predetermined position the brake lever is lifted and allows the beam to let-off a short length of warp. When properly set the warp is let-off a very small amount each pick and no weight adjustment is necessary as the warp weaves down. For plain fabric the spring-loaded back-rests assist in keeping an even tension during shedding.

Another improvement is seen in the Saurer high-speed loom, Fig. 12A, in which the warp passes in sheet form round a felt-covered drum. This has a cord and weighted lever brake. There is also a spring tension on the warp beam carrier which is easily altered by a thumb screw. Most of the tension is applied by the felt covered drum and as this is on the yarn itself and not on the beam it is very effective and when once set requires little or no adjustment.

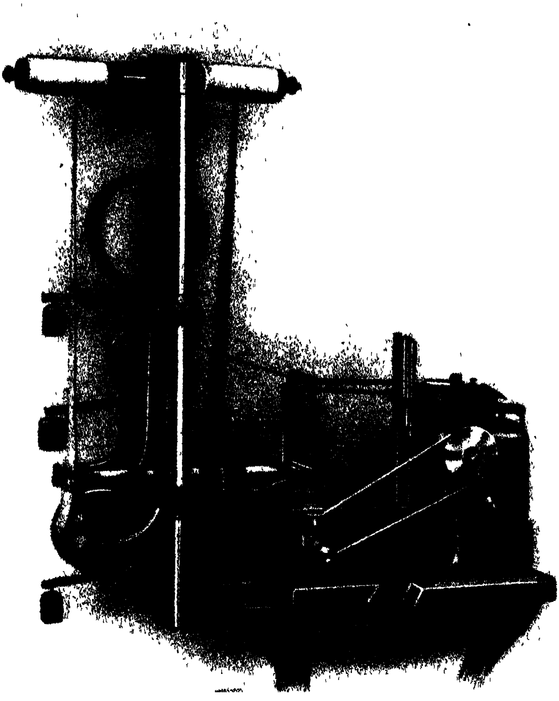

Fig. 12a

Take-Up Motions

In the early types of looms, taking-up was very simply done by taking the fabrics round a rail below the breast piece then under the loom, up to the top castle, then down to a weighted pulley, up again to the top castle and down to a rail at the back of the loom, where the tapes, etc. were wound on to small beams by hand or passed through slots to be held by wood wedges. The amount of weight on the pulley as compared with the weight on the warp determined the picks per inch. It can be imagined that a fair amount of skill on the part of the weaver was necessary to keep the picks regular.

Another early type, one in which a roller underneath the breast piece was turned by gearing, the tapes being wound up on the roller, was made. As the rolls increased in diameter the picks per inch were reduced and frequent adjustments were therefore necessary.

We next find a sand roller being used, driven at a constant speed by worm-gearing from the second motion shaft. In addition to the sand roller is another roller driven from it at a slightly higher surface speed and on this are pressed a series of small rollers, one for each piece, their function being to take the woven tapes away from the sand roller.

There are also intermittent take-off motions with the same arrangement of rollers, where a ratchet wheel is driven forward by a pawl each pick, Fig. 8. To change the picks per inch, a ratchet wheel with more or less teeth is substituted. This is not very good as the movement of the pawl has to be altered to suit the new wheel. It does not seem to have occurred to smallware machinists to fit a motion similar to Pickle's take-up motion, where changes in picks can easily be made by changing a small gear wheel.

In the Saurer multi-piece loom it is not necessary to change any wheels to alter the picks per inch. A gear box is fitted with an ingenious arrangement of parts whereby it is only necessary to move two pointers, Fig. 6, to the number of picks per inch required. Changes can thus be effected in an instant without any tools or spare wheels being necessary.

Single Piece Loom

No paper with this title would be complete without mention of the Saurer high-speed loom, Figs. 12 and 12A. This is a single shuttle loom and has several novel and excellent features. Each small unit is a loom complete with all the necessary motions and is so well designed and made that it is practicable to weave 150 denier artificial silk weft twist and unsized, at 700 to 800 picks per minute.

In addition to the warp tension previously mentioned there is a warp-stop motion, also vibrating back-rest which keeps the warp tension constant during shedding. The shedding motion is limited to four shafts and four picks per repeat. The healds are Grob flat steel in metal frames, connected positively to double cams and are thus positively controlled. There is also a further connection by levers to a point near the beat up so that the heald eyes move in the arc of a circle with the point of beat-up as centre. This prevents undue friction in the heald eyes.

Perhaps the most novel feature of this loom is the split reed. This consists of two parts like small combs with short flat teeth. The botton teeth are wedge shaped. Both combs are mounted in a frame which has a vibrating vertical motion. The teeth of the top comb overlap slightly and are immediately in front of those in the bottom so that the warp threads can pass from top to bottom of the reed in the same dent when the shed changes. When the shuttle passes through the shed the weft is laid behind the teeth, the whole frame rocks downward from a centre, at the same time the top teeth move backwards to form an opening through which the weft slips, the teeth close together and the frame moves upwards, the weft being pushed forward by the wedge shaped formation of the bottom teeth. This movement is very small and there is thus very little friction on the warp during beating up. There are no swinging battens as in ordinary loom and the high speed gives very little vibration.

The shuttle is positively driven in a flat semi-circular race and an extension lays the weft very near the fell so that there is no slack weft to deal with when the shuttle returns. There is also an ingenious weft stop motion which stops the loom immediately the weft breaks or runs out.

The loom is driven by means of a simple clutch and when this is opened a band brake comes into operation to give a quick stop. To facilitate turning of the loom by hand the brake is released by moving the starting handle to a third position. The take-off motion consists of a roller with a knurled surface driven by worm and wheel gearing, the ribbon is pressed against this roller by means of a spring-loaded rubber roller.

To alter the picks per inch two cut gears are changed. As these wheels are made in pairs no adjustments are necessary when changing. The ribbon when made is wound on to a tube in the form of a cross-wound cheese, each tube being capable of holding a week's production.

All the parts are made to a degree of mechanical accuracy seldom found in looms and naturally the cost is high. The attention required for their upkeep is necessarily exacting and these two facts no doubt have prevented their more general adoption by the trade.

There are still a large number of interesting problems, to solve which it is necessary to correctly understand the problem, to have properly equipped and enterprising machine makers, and manufacturers who are willing to pay a proper price for a well-designed, properly-constructed machine, and workpeople who are willing and able to adapt themselves to new conditions.

NOTES AND NOTICES

Conference Papers and Discussion

In regard to the discussions which followed the presentation of papers at the recent Conference of the Institute at Grange-over-Sands, recorded in this issue, a departure from normal procedure has been pursued. Contributors to discussion have been invited to provide written statements covering their observations. By this means, no question is likely to arise as to the accuracy of the record and a vast amount of checking is obviated. Given anything like general co-operation on the part of contributors—so far the response has been quite good—this method of recording discussion, which has been successfully carried out in connection with other conferences, should prove most satisfactory. Moreover, it is suggested that the field of discussion might be advantageously extended if members who were unable to attend the Conference would, after reading the papers published in this issue, communicate any observations considered suitable for publication. The discussions, including author's replies and all written communications received in time, will appear in the July issue.

Staffs of Textile Colleges

Changes have been fairly frequent of late in regard to the staffs of textile training institutions. Mr. S. Kershaw, F.T.I., Lecturer in Spinning at Bradford Technical College, has been appointed Head of the Textile Department of Halifax Technical College and is to enter upon his new engagement on the 1st September. A former evening and day student at Bradford, Mr. Kershaw became attached to the part-time teaching staff of the College in 1910 and, after a period as Assistant-Lecturer at Huddersfield, was appointed to the staff at Bradford eleven years ago. His record of service in industry comprises the occupation of posts of Manager, Richmond Combing Co. Ltd., Bradford; Cone Drawing Manager, Messrs. Salt, Saltaire; and Manager, Messrs. Hindle & Firth Ltd., Bradford. Author and joint-author of text-books on Worsted Manufacture, and Carbonising, Mr. Kershaw has long been actively associated with the Textile Institute, and he is a member of Council and a member of the Library Committee and the Yorkshire Section Committee. The vacancy at Halifax is created by the impending retirement of Mr. Harry Turner, F.T.I., a former day and evening student of his college. The Halifax College was opened in 1896, and Mr. Turner has attended, as student, teacher, and Head of the Textile Department respectively, since 1897. He was promoted to the position of Head of the Spinning Department in 1903 and to Head of the Textile Department in 1919. Mr. Turner intends to proceed to Vancouver, British Columbia, immediately on retirement.

Recent Appointments

Mr. F. L. Barrett (Fellow), who has for some years been associated with Mr. W. Kershaw (Fellow and Chairman of the Publications Committee) in the Research and Chemical departments of the Bleachers' Association Ltd., has been appointed Manager of Messrs. John Stanning & Son Ltd., Leyland, a branch of the Association. Prior to his appointment with the Bleachers' Association, Mr. Barrett was a member of the Research Staff of Messrs. Tootal Broadhurst Lee Co. Ltd. He has been a Fellow of this Institute for the last eight years and is also a Fellow of the Institute of Chemistry.

An Associate of the Textile Institute, Mr. W. W. Manton, of G. & J. Slater Ltd., Dunscar Bleach Works, has recently been promoted to the position of Manager of this branch of the Bleachers' Association Ltd.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (April issue of this *Journal*)—

FELLOWSHIP

SUDDARDS, Walter Haley (Shipley)

ASSOCIATESHIP

HARDACRE, William (Keighley)
MYERS, Joseph (Bradford)
PRITCHARD, William (Derby)

Institute Membership

At the June meeting of Council, the following were elected to Membership of the Institute—*Ordinary:* G. Blumer (Special Student, College of Technology, Manchester); H. R. Hall, Cheadle Textiles Ltd., Tape Street, Cheadle, N. Stafford (Textile Manager); F. B. Martins, B.Sc., Cia Nacional de Tecidos Nova America, Rio de Janeiro, Brazil (Managing Director, spinners, manufacturers, and finishers of cotton and cotton and rayon goods); T. A. Paterson, Stephen Clark and Co., Millwrights and Engineers, Alva, Clackmannanshire (Joint Partner, makers of teasers for woollen trade); H. J. Stern, B.Sc., Ph.D., A.I.C., The Chestnuts, Cambridge Park, Wanstead, London, E. 11 (Consultant and Chief Chemist, India Rubber, Gutta Percha and Telegraph Works, Co. Ltd. Silvertown); F. A. Prisley, B.S., c/o Wanskuck Mills, 725 Branch Avenue, Providence, R.I., U.S.A. (Chemist); C. G. Winson, B.Sc., A.I.C., Research Department, Textile Laboratory, L.M. & S. Railway, Derby (Research Assistant to Textile Technologist); *Junior:* H. Hacking, 309 Entwistle Road, Rochdale (Statistical Assistant, British Cotton Industry Research Association, Shirley Institute).

ACKNOWLEDGMENTS

The Publications Committee wishes to acknowledge the following loans of blocks used in the illustration of the foregoing Conference papers—

Paper by W. English and F. Nasmith—P153. Blocks lent by Universal Winding Co., Manchester, and by Cook & Co., Manchester.

Paper by J. W. Pennington—P225. Blocks lent by Thomas Holt Ltd., Rochdale; Universal Winding Co. Ltd., Manchester; Livesey & Crowther Ltd., Manchester; and John T. Murray, Manchester; Butterworth & Dickinson Ltd., Burnley; and *The Textile Manufacturer*, Manchester.

Paper by W. Holt—P295. Blocks lent by Schweiter Ltd., Zurich (Livesey & Crowther Ltd., Manchester); T. F. Wilkinson Ltd., Coventry.

THE JOURNAL OF THE
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PROCEEDINGS

EXAMINATION OF THE INSTITUTE

For the current year, the Examination of the Institute, in connection with applications for the Associateship, took place on the 13th June (Part I) at Manchester, and on the 20th June (Part II) at Manchester, Nottingham, Belfast, Dunfermline, Quebec, and Calcutta. For the information of members and others interested the examination papers are recorded as follows—

EXAMINATION PART I (Auxiliary Subjects)

CHEMISTRY

9.45 *a.m. to* 11.15 *a.m.*—13*th June* 1934

Candidates to answer THREE out of FOUR questions

(1) What do you understand by the term "hard water"? Describe those properties of hard waters of particular importance in industry.

(2) $2KClO_3 = 2KCl+3O_2$ (K = 39, Cl = 35·5, O = 16).
Say what information you may obtain from the above equation.

(3) Write a short essay on the production of hydrogen by the interaction of zinc and dilute sulphuric acid. What weight of commercial zinc containing 95% pure zinc and 5% non-metallic impurity would be required to produce sufficient hydrogen to fill, at 0° C. and normal atmospheric pressure, a balloon of capacity equal to that of a sphere 10 metres in diameter.

(4) How would you define a chemical compound? Carbon-dioxide is soluble in water. State whether in your opinion the aqueous solution of carbon-dioxide is a mixture or a chemical compound, and give reasons for your answer.

PHYSICS

11.30 *a.m. to* 1.0 *p.m.*—13*th June* 1934

Candidates to answer FOUR out of SEVEN questions

(1) Describe how you would measure the cubical expansion of a liquid.

(2) A clock, fitted with a brass pendulum, keeps correct time at 0° C. How much will the clock gain or lose after a week's run at 20° C.? You are given that the time of oscillation of a pendulum varies as the square root of its length and the coefficient of linear expansion of brass is 0·000018.

(3) What do you understand by "the relative humidity of the air"? Describe a method of measuring it.

(4) How would you demonstrate that white light is a mixture of many colours? If illuminated by light transmitted through red glass, what would be the colour of a piece of (1) white paper, (2) green paper? Give reasons for your answers.

(5) Define the focal length of a lens. A convex lens has a focal length of 9 ins. Where must an object be placed to give a real image which is one-third the size of the object ?

(6) How would you compare the electromotive forces of two cells if the following apparatus were provided—tangent galvanometer, reversing switch, and a length of resistance wire ?

(7) Describe the potentiometer method for comparing the electromotive forces of two cells.

MATHEMATICS AND MECHANICS

2.0 *p.m. to* 4.0 *p.m.—13th June* 1934

Candidates are required to answer TWO, and not more than TWO, questions from EACH section

Section A

(1) (i) Simplify— $\frac{2x^2-x-1}{2x^2+5x+2} \times \frac{4x^2+x-14}{16x^2-49}$

(ii) Solve $\frac{2x}{3}+y=16$

$x+\frac{y}{4}=14$

(2) (i) What is a logarithm ?

(ii) Evaluate $\frac{17{\cdot}03 \times \sqrt{643{\cdot}2}}{0{\cdot}036 \times 27{\cdot}4}$

(iii) If $t=6{\cdot}28\sqrt{\frac{k^2}{gh}}$ express g in terms of t, k, and h.

(3) State a formula for the sum of an Arithmetic Progression. In boring a well 300 feet deep, the cost is 2/6 for the first foot, 2/7 for the second foot, 2/8 for the third, and so on, the cost increasing 1d. for each additional foot. Find the cost of boring the last foot and also of boring the entire well.

Section B

(4) With the same axes and scales draw the graphs of $y=x^3$ and $y=3x+3$ between $x=-3$ and $x=+3$. From your graphs find, approximately, a value of x which satisfies the equation $x^3-3x-3=0$.

(5) A wireless mast stands on level ground. Two points A and B on the ground are due East and due West of the mast respectively, and the distance AB is 120 yards. If the angle of elevation of the top of the mast from A is 60° and from B is 45°, find the height of the mast in feet.

(6) From a point P two tangents PQ and PR are drawn to a circle. Prove that these tangents are equal in length. If PQ is 12 in. long and the length of the shortest line from P to meet the circle is 8 in., find the radius of the circle and the length of the chord QR.

(7) A tank is 4 ft. 6 in. square at the top, 3 ft. square at the bottom, and 4 ft. deep. How many cubic feet of water will it hold ? What will be the depth of water when it is half full ?

Section C

(8) What do you understand by (i) Power, (ii) Horse-Power, (iii) Efficiency? An engine works a pump and lifts 400 gallons of water per minute through a height of 50 feet. If the overall efficiency of the pump is 60%, at what horse-power is the engine working? (1 gallon of water weighs 10 lb.)

(9) A simple pendulum is 5 feet long. Find the time of a complete vibration. If it swings through 20° on each side of the vertical, find the velocity of the bob when passing through its lowest position.

(10) Define—"Coefficient of Friction".
A weight of 56 lb. rests on a plane inclined at 30° to the horizontal, the coefficient of friction being 0·25. What force acting up the plane will be required to prevent the weight from sliding down?

ESSAY

4.15 *p.m. to* 5.45 *p.m.*—13*th June* 1934

Pay special attention to the paragraphing, punctuation, spelling, and handwriting

Write not more than 5 pages on ONE of the following subjects—

(*a*) A Pleasure Fair.
(*b*) The B.B.C. Programmes.
(*c*) The Drought.
(*d*) Modern Advertising.
(*e*) Road Transport *v.* Rail Transport.
(*f*) Slum Clearance and Town Planning.
(*g*) "The Unchanging East".
(*h*) Liberty, Equality, and Fraternity, how far are they possible or desirable?

EXAMINATION PART II

GENERAL TEXTILE TECHNOLOGY

SECTIONS I AND V OF SYLLABUS

10 *a.m. to* 1 *p.m.*—20*th June* 1934

Candidates to answer THREE out of FOUR Questions in each Section

Section I—Fibres and their Production

(1) Give the trade descriptions and countries of origin of wools suitable for (*a*) botany worsteds; (*b*) knitted underwear; (*c*) Cheviot suitings; (*d*) high-quality carpets; (*e*) linings.

(2) Make sketches of the appearance under the microscope, both in longitudinal view and in transverse section, of the following fibres:—normal cotton; immature cotton; mercerised cotton; well-retted flax; lustre wool; merino wool; raw silk, in the condition as reeled.

(3) Explain how the following materials are obtained, give their characteristics, and state their uses in the textile industries:—kapok; tinsel thread; wire yarn; paper yarn; Angora rabbit hair; ramie; round latex thread.

(4) What are the differences between viscose and acetate rayons and how are their distinctive properties utilised in textiles?

Section V—Analysis and Testing of Raw Materials, Yarns, and Fabrics

(1) You are asked to examine a dyed "silk" fabric. How would you determine whether it is in fact real silk or rayon ? If found to be rayon, how would you identify the type ?

(2) What are the particulars you would require to determine from a sample of fabric in order to be able to produce an exact copy ? State the kind of fabric you have in mind in making your answer and describe in detail how you would obtain the required particulars if your sample measured only 4 in. square. To what extent would the results of tests on so small a sample be reliable ?

(3) A fabric manufactured from mercerised cotton yarn, and afterwards piece dyed, shows irregularity in colour. How would you examine this fabric in order to find whether the fault is due to uneven mercerising or uneven dyeing ?

(4) Discuss various forms of warp stripiness in finished fabrics in relation to (*a*) determining the cause of the defects, and (*b*) preventing their recurrence. You may confine your discussion to any one class of fabric.

SECTIONS II, III, AND IV OF SYLLABUS

2.30 *p.m.* to 5.30 *p.m.*—*20th June* 1934

Candidates to answer TWO out of THREE Questions in each Section

Section II—Conversion of Fibres into Finished Yarns

(1) Compare and contrast (*a*) woollen and worsted yarns, (*b*) carded and combed cotton yarns, from the point of view of structure, nature of raw materials used, and method of processing.

(2) What are the features of raw material, preparation, and spinning which influence strength, elasticity, uniformity, and density of yarns ?

(3) What are the fundamental differences between the method of drafting used in Arkwright's water frame and that used in Hargreaves' spinning jenny ?

Section III—Conversion of Yarns into Fabrics, and Fabrics produced by Special Methods

(1) In the utilisation of rayon yarns for warp and weft purposes, certain modifications are required in machinery and methods generally employed in the winding, warping, and beaming of cotton and worsted yarns. Describe the modifications and give reasons for their adoption.

(2) Compare the characteristics of woven and knitted fabrics. Make sketches showing the fundamental features of a modern weaving loom and of a circular knitting machine.

(3) Explain by the aid of rough sketches how a Jacquard machine employed as a loom shedding motion is capable of producing larger and more varied ornamental weave pattern effects than can be produced by a loom dobby shedding motion.

Section IV—Conversion of Fabrics into Finished Materials

(1) Distinguish between mechanical and chemical finishes as applied to textile fabrics. Give appropriate examples.

(2) Give some examples of the way in which dyeing faults may be produced in (*a*) woollen or worsted fabrics, and (*b*) cotton or linen fabrics, by alteration in the affinity relations between dyestuff and fibre during scouring and bleaching.

(3) Describe the methods commonly used for the removal of water from textile fabrics after any kind of wet-processing.

Annual Conference—Grange-over-Sands
23rd to 25th May 1934

As noted in the June issue (page P311) the discussions following the papers read at above Conference have been secured by direct collaboration with the Chairmen, Speakers, and Authors of papers, and are printed hereunder. It is to be noted that the response to this procedure has been practically 100% and it is hoped that the result is commensurately the more useful. The title and author of each Conference paper appears in the same order as in the June issue, so that easy reference to the papers themselves is possible.

SOME NOTES ON THE CONSTRUCTION AND APPLICATION OF IMITATION BACKED AND IMITATION DOUBLE WEAVES

By A. YEWDALL, F.T.I.
(Department of Textiles, The University, Leeds)

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DISCUSSION

Professor F. Bradbury, Belfast, stated that the designs submitted by Mr. Yewdall were ingenious and novel in construction and effect. He asked why the author called them imitations of types of cloth they did not represent. Backed and doubled cloths were a necessary evil. Their beauty was not enhanced, notwithstanding a relative increase in weight and cost. It was usual to imitate something better. It was possible to understand the significance when the terms "Imitation Gauze" or "Leno" and "Loop or Pile Fabrics" were used; though it would be better if the same word always meant the same thing.

Mr. Yewdall in reply, said that he called them "Imitation" because the inventor of the system used that designation. Also, in his view the word "imitation" did not carry the implication of inferiority as conveyed by the modern attributive sense or understanding of that word, but rather its much older meaning of "a copy or reproduction". An imitation backed or double weaving, therefore, signified a copy or reproduction of a certain pattern effect by another means.

Reference having been made to sateen-backed and venetian weaves, Mr. D. R. Christie, Galashiels, detailed uses of the 2–3 interlacing on various rearrangements for drafted styles in worsted suitings. The cloth was over-sett in the warp and this gave to the back a smooth sateen appearance with fine twill.

Dr. T. Oliver, Galashiels, was doubtful of the historical paragraphs. He had analysed similar patterns from Homo & Cie, Paris, 45 years ago. So that although Professor Donat (then at Reichenberg, Bohemia) might well have been the first public demonstrator of the type of design, it was unlikely that he originated the structure. Professor Beaumont certainly invented the name "imitation back" when the first designs reached teaching circles in this country, 35 to 40 years ago. As to the criticism that the design types took many heald shafts and small yarns, the same might be directed against all backed cloths. It should be remembered that the structure was much stronger than the corresponding normal backed cloths.

Whether Donat was the actual originator or inventor of imitation backed weaves or not, replied the lecturer, he certainly systematised their construction and introduced them to the teaching world. With regard to the Homo & Cie patterns, it was possible that these were modifications of corkscrew weaves—being popular with designers of that day—and that Donat got his inspiration from them.

As ideas on what constituted normal setting varied so much, Dr. A. W. Stevenson, Galashiels, asked if Mr. Yedwall would give a sett for a common twill which would be comparable with those given for special weaves in his paper.

In reply, Mr. Yewdall said that a common setting for a warp backed weave made on the 1–and–1 system with a 2-and-2 twill face and 3-and-1 twill back, and woven with 2/40's worsted, was 120 ends and 60 picks per inch, sett 68 in. wide in the reed. This could be applied quite satisfactorily to Fig. 2. Many of the setts applied to weaves set forth in the paper had been taken from their corresponding true backed weaves. (Weaves made on the 3-and-1 system excluded.) All the imitation double weaves are sett exactly like their corresponding true double structures.

LOOMS FOR THE SILK AND RAYON INDUSTRIES WITH REFERENCE TO THEIR STRUCTURE AND PERFORMANCE

By Dr. Ing. E. Honegger
(Federal Institute of Technology, Zürich)

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DISCUSSION

Mr. A. E. Delph, Bocking, inquired whether the flat pirns were suitable for rayon yarns as well as natural silk and whether there was a greater liability for rayon yarns to be strained when winding on to these pirns than winding on to pirns with a circular cross section.

Dr. Honegger replied that tests with flat pirns had been carried through for a considerable period using rayon as well as silk; the pirns proved perfectly suitable for both fibres. Yarns were not strained more whilst being wound on flat pirns than on ordinary pirns with a circular cross section: the vibrating pull acting on the yarn was liable to reduce the yarn friction and to reduce the strain accordingly.

Mr. J. Hollas, Preston, asked for information on three points—

The Take-up Motion—Dr. Honegger had only referred to the direct take-up, that was, the one in which the cloth was wound directly on to the take-up roller and not passed forward to a roller below. French silk and artificial silk manufacturers largely used the indirect take-up. Did Dr. Honegger consider the direct take-up altogether superior to the indirect ?

In respect of the Direct Take-up—Was there not very considerable wear of the pawls in the ratchet motion ? He understood that in a shed of 300 looms, one man was required to adjust the picks consequent upon the wear in the take-up motion. He understood that the pawls in the ratchet had to be overhauled within 7 years.

In respect of the Centre Weft Fork and the mechanism which pulled up the slay before the broken pick was beaten up to the fell of the cloth; did not this brake mechanism put a heavy strain on the loom ?

Replying to Mr. Hollas, the lecturer said—

(1) He considered the direct take-up motion to be superior to the indirect one, because the fabric was taken straight to the cloth beam without enduring any rubbing action round the sand beam. This advantage might be of great importance when weaving particularly delicate and fine fabrics. However the indirect take-up motion would do no perceptible harm whatever to less susceptible cloths. As a general rule, silk and rayon were far more liable to be injured than yarns built up of short fibres.

(2) The wear of the pawls in the ratchet motion was not known to him to have been a source of trouble, though such motions had been in operation for decades They would need overhauling once every 7 to 10 years, but otherwise they did not require any particular attention, except regular oiling. The fact that with the direct take-up motion a man had to look after the picks was not due to wear of any moving parts, but to the necessity of adjusting the motion. To give the best results, the automatic direct take-up motion required a certain degree of attention: though the motion would be adjusted automatically when the cloth beam diameter augments; the adjustment must be controlled periodically. It

was quite possible that one man might be required to look after the take-up motion of 300 looms, particularly if they were weaving different and often-changing articles.

(3) The centre weft fork was working so rapidly that if the weft was broken the loom must not be stopped abruptly, but whilst the crankshaft rotated through say 45°. The strain put on the loom by the brake mechanism was far smaller than the one produced by dropping the stop rod nib.

Mr. H. C. Barnes, Manchester, inquired whether Dr. Honegger could further explain principle or practice in using the inclined reed at the beat-up.

Dr. Stevenson, Galashiels, asked whether there was any detrimental sawing action of the reed on the weft when the former was used in an inclined position.

Replying to these two speakers Dr. Honegger said that, as to the principle in using the inclined elastic reed at the beat-up, he was afraid he could not add much to what he had said in the paper itself: this kind of reed would be used for the most delicate fabrics, such as china crêpe, as it would give a very soft and perfectly equal beat-up.

No perceptible sawing action was produced by the inclined reed on the weft as long as the wires were in a correct state: the wires would touch the weft during a very short time only, and the weft would glide along the wires a very little way. The pressure between the wires and the weft would also be very small, and would not leave any mark on the weft. A sawing action might be noticed however if the reed wires had particularly sharp edges. Sharp edges would not be produced by wooden shuttles, but might be produced if shuttles with coatings of material liable to sharpen the wires were made use of, *i.e.* of vulcanised fibre.

A BRIEF SURVEY OF CARPET MANUFACTURE WITH SPECIAL REFERENCE TO THE MAJOR INVENTIONS AND NOTES ON CHANGES IN DESIGN

A. B. Roth, B.Sc., A.T.I.

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DISCUSSION

Professor Bradbury, Belfast, from the chair said that the manufacture of carpets was reasonably included among the first of the Industrial Arts, because carpets were as much a necessity as a luxury. In modern days the soul of the room or department was the carpet. The possibility of structural development in, the application of colour to, and the display of distinctive qualities of decoration, to carpets was unlimited. The increased employment thus afforded was obvious whether the carpets were manufactured for home consumption or export. He was pleased to be the chairman, not only because he had done some work on carpets himself but also because the speaker was the son of the late H. Ling Roth, whom he had known and who was known of his researches on "Primitive Looms".

Mr. W. Wilkinson, Blackburn, asked for the speed of the Tapestry Carpet Loom.

Mr. Roth in reply said the number of picks or shots of weft per minute in Tapestry looms varied from 86/90 in the case of ¾ wide ones to 40/44 in 16/4. The number of wires was obtained by dividing these by Two, Three, or Four, according to the number of picks per wire.

Mr. H. Busfield, Leeds, asked—

(1) Would Mr. Roth express his opinion for the decline in the use of worsted yarns for carpet manufacture, and why woollen yarns had considerably replaced them ?

(2) Also if it was likely that worsted yarns would regain the popularity they had some years ago ?

Replying to Mr. Busfield, the author said that before the time of the general manufacture of tufted carpets worsted was generally used: it gave to looped pile fabrics—Brussels and Tapestry—the cover required (a two-fold yarn loosely twisted reverse way to give a flat yarn). In cut pile—Wilton and Tapestry velvet—it gave clearness of outline owing to the small unit used in designing. Woollen yarn was used generally in Chenille. With tufted carpets the unit was comparatively coarse. Woollen yarn was also used largely at present in Wiltons and Tapestry velvet. There did not yet seem to be any tendency away from carpets designed on the basis of coarse units.

A SURVEY OF SPECIAL LOOMS OF BRITISH ORIGIN

By J. Starkie, A.T.I.
(Municipal Technical School, Nelson)

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DISCUSSION

Mr. A. Anderson, Blackburn, referred to the lecturer's preference for the large diameter take-up on the auxiliary cloth winding motion in Fig. 3. In his opinion this system was best applied to real silk goods, since when used in weaving rayon goods slight imperfections arose after pick finding. Could the lecturer suggest a means to obviate this trouble ?

Mr. Starkie, replying, said that the method usually adopted was to use some form of spring-back rest in conjunction with a roller of large diameter, the object being to maintain an even warp tension during the process of pick finding.

Mr. W. Wilkinson, Blackburn, made remarks concerning the use of more refined looms for high grade fabrics. He was of the opinion that the manufacturers were attempting too much and they would ultimately be compelled to equip their mills with machines and looms specially built for these special fabrics. The idea that the looms should be simple might be a mistaken policy and we should not be too keen to use modified power looms for all grades of fancy fabrics. The lecture given by Professor Honegger reflected the views of the continental loom makers and it was suggested that our machinists should carefully consider the question of more refined machines and looms to meet the requirements of our changing industry.

Mr. J. W. Pennington, Burnley, referred to the question of quality of cloth produced on looms specially constructed for weaving rayon fabrics compared with that of cloth produced on the ordinary Lancashire loom converted and adapted to the needs of rayon weaving and operated by the Lancashire weaver. There was no disputing the fact that better quality cloth could be and was being made on the specially-constructed loom, but there were many difficulties to overcome before such looms could become universally used in Lancashire. At the present time, probably more than 95% of the rayon fabrics produced in Lancashire were made on ordinary Lancashire looms converted and adapted to the needs of rayon weaving, and it was surprising what had been achieved by the skilled weaver, on this type of loom. There were many manufacturers who had experimented with a few of the specially-constructed types of loom, but for many reasons had not met with any great degree of success. One of the chief being that the Lancashire weaver having been brought up on the ordinary loom did not take too kindly to the new type. It took some considerable time to become efficient and skilled in the manipulation of a loom which was more difficult and complicated in its mechanism. It had generally been found that the older type of operative had too much to unlearn and in the process considerable quantities of cloth were spoiled. The best results had been secured where the looms had not been mixed with other ordinary types and where young operatives and young overlookers suitably trained in the tuning of the new type of loom had been employed.

In order that the change from one type of loom to another should not be too great some manufacturers preferred to use a loom which was a combination of a real silk loom and a Lancashire loom. The loom was more accurately made and embodied refined features in its mechanism, suitable to the needs of rayon weaving. With a loom of this type operatives readily become skilled and less cloth was spoiled in the change-over process. Excellent results had been achieved with looms of this type which were not quite so costly as the continental type of silk and rayon loom. Again quite a large number of manufacturers preferred to rely on a good circular box loom with certain modifications for rayon weaving. This type of loom enabled them to cope with a wider range of fabrics. It was a very difficult problem to decide.

Mr. J. H. Strong, Blackburn, asked if the lecture referred to rayon fabrics only, and the lecturer said it did. Mr. Strong then said that the title should be corrected and the remarks regarding machinery in Lancashire being, in very many cases, out of date, should be corrected to refer to rayon weaving only. He also pointed out that circular box motions had the advantage not mentioned by the lecturer of enabling the loom to run at more picks per minute than a drop box loom.

The lecturer said he had hoped that it was quite clear that any special looms which were being introduced were intended generally for modern fabrics which usually contained rayon yarns. In regard to circular box looms, the advantage of speed was not so important as the disadvantage mentioned; it was well known that the best results were obtained with rayon yarns when using a reduced loom speed.

Mr. W. Holt, Tean, said that Lancashire was trying to get looms for artificial silk fabrics built to suit the existing tacklers. In his opinion this was wrong. A modern loom built by up-to-date engineers to fine limits of accuracy, needed an engineer, trained to work to these fine limits, to keep it in order. He had proved this with a plant of high-speed ribbon looms. When the first group of looms was bought, the makers sent out an expert who was first a mechanic and afterwards a weaver. After trying out the looms for some time he introduced a youth who was a good mechanic but knew nothing of weaving and gave him six months training under the expert. He was then left in charge of the mechanical part of the job, whilst a textile man had charge of the weaving. This arrangement had proved very successful.

Mr. W. H. Slater, Manchester, said that in his opinion the problem at this moment was economic, not mechanical. Dr. Honegger had suggested "Rolls Royce" machinery at "Rolls Royce" prices, with which he was in favour, while Mr. Starkie proposed minor adaptations to existing Lancashire cotton looms to make them "efficient" on silk and rayon. Mr. Slater stated that it was the duty of cotton industrialists to approach bankers and financiers and present their full case of the shortage of liquid capital to buy modern machines. If liquid capital was not forthcoming then the cotton industry would "go out" in Lancashire.

Mr. Starkie said his paper was a description and criticism of what was being done rather than a proposal of what should be done. The modifications to existing looms which had been mentioned were carried out in cases where the installation of new looms was not a practical proposition.

Mr. J. Hollas, Preston, said that the lecturer had dealt largely with modifications of looms for weaving artificial silk. His experience was in respect of three mills where real silk looms were weaving side by side with modified Lancashire looms. The cloth-lookers as they got a piece of cloth in the warehouse could tell whether it was from a real silk loom or a modified Lancashire loom. Undoubtedly, the silk loom produced a higher grade fabric than the modified Lancashire loom.

SOME WINDING INVESTIGATIONS AND DEVELOPMENTS

By W. English, M.Sc.Tech., F.T.I., and F. Nasmith, F.T.I.
(Universal Winding Co. Ltd., Manchester)

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DISCUSSION

Mr. G. H. Thompson, chairman, said clearing with the plates with slots set at 2·6 times the diameter of yarn would indicate that a low quality yarn was used. This was borne out by the amount of fluff shown in the photographs. A better quality yarn with closer set plates would have lent itself to better analysis of the cause of breaks and would have been nearer the Lancashire practice. A slub catcher at the ring frame would prove to be too expensive, unless it were for experimental purposes, as much waste would result.

As stated in the paper, said the lecturer, the wide setting was decided upon because the object of the investigation was to reduce costs rather than to improve quality. The fabrics being produced, namely, sheetings, were of a highly competitive line, and it was in order to reduce stoppages and so increase output and reduce costs that the investigation was carried out. It was perhaps too early yet to say how the ring frame slub catcher would work out economically, but there was no doubt that one important result of its use had been the increased attention which everybody concerned from the management to the piecer, was paying to the prevention of slubs where the lappet was in use. This might have far-reaching results in reducing costs.

Mr. P. A. Bentley, Leicester, agreed that a slub detector was a great asset, and it would be a greater asset if it could be made into a slub eliminator, especially so in yarn for the knitting trades. Mr. Nasmith had mentioned a "Klots" slub detector. He agreed with Mr. Nasmith that a slot was certainly a gauge, but at the same time it was a gauge with two flat sides. He asked if they had tried two slots—one slot placed 1 in. behind the other and at right angles, which might eliminate quite a lot of slubs that would pass the ordinary single-slot slub detector. In fact, he was not quite sure if it would not be advisable to try four or more, so long as there was an inch between each one, thus avoiding trapping the slub too much before coming on to the next slot. However, that was only an opinion.

The removal of any and every kind of slub, said Mr. Nasmith, especially of soft slubs, was not an easy matter, and was outside the scope of the present paper. They had carried out a considerable amount of work on this problem from time to time, but much more required to be done before any very definite statements could be made. They realised its importance, not only in the knitting but also in the lace and allied trades, and there was no doubt that further investigations regarding the effectiveness of slubcatchers for these qualities would be extremely useful. The arranging of two slubcatchers, one behind the other, the slots at right angles, had been tried. The disadvantages were that fibre buttons were formed very quickly, and the threading of the yarn was more complicated. Also, the fact that the yarn was restricted to one point in each slot caused rapid wear, rounding the edges of the plates and so reducing the effectiveness of the slub-catchers. Of course repetition of slub-catchers was bound to cause more slubs to be trapped, but it was also likely to make more slubs through excessive abrasion, and this was a point that should always be carefully watched when experimenting with slub-catchers. Finally there was the question of winding costs; it was remarkable how these costs rose and production decreased when keen slubbing was adopted, so that it was only where the quality justified the extra expense that it should be attempted.

Mr. W. H. Slater, Manchester, complimented the authors on the amount of research work which had been done in this little-known field in this country. He disagreed with the views expressed by previous questioners, as the paper catered specifically for that coarse and medium section of the trade in Lancashire which had previously ignored this all-important subject.

Mr. Slater, said the lecturer, had drawn attention to the main object of the work, which was to endeavour to reduce costs on ordinary and even on low qualities, not only by removing at preparatory processes yarn imperfections which would otherwise cause loom stoppages, but also by showing that closer collaboration between the preparatory departments and the spinning mill would result in the prevention of many of these defects. In short, it was claimed that slub-catchers on winding machines were not refinements for high quality yarns only, but were essential to all modern winding systems, and when correctly designed and applied, could bring about reductions in processing costs.

Mr. J. Crompton, Ansdell, whilst commending the different methods of clearing yarn displayed by the contributors of the paper, recommended that the weaver should be paid to pick out any bad piecings or knots which had escaped the clearer. In this way tangible evidence of faulty work could be brought home to the spinner, and on the principle that prevention was better than cure, more perfect work could be secured, and possibly clearers entirely dispensed with.

The lecturer replied that Mr. Crompton's suggestion was good where high-quality work was being produced, but for ordinary qualities and where cost of production was of first importance, the slubs should be removed mechanically at an earlier stage. The "tangible evidence of faulty work" could be brought home to the spinner just as effectively from the winding room, and in fact this was advocated in the paper. But whether the spinner would ever provide a yarn which would enable us to dispense with clearers was a question the authors preferred to leave unanswered.

Dr. F. T. Pierce, Didsbury, said there had been some discussion of the settings and objects of clearing for various qualities; on which the only guidance was the advice of the manufacturer concerned. Was there any general criterion of the settings to be used and the standard of clearing demanded for various counts and qualities, when cleared either for the removal of imperfections or for economy in cost of processing ? Again, clearing was used to remove local imperfections. Was it ever used to reject cops or deliveries which failed to reach a required standard by showing an excessive number of breakages, or could the devices be easily adapted to this purpose ?

In reply to Dr. Peirce, the lecturer thought that there was no general criterion by which the slub-catcher settings were determined. Important considerations were the quality of the yarn and the subsequent processing or uses to which it was to be put. At one extreme were yarns for which no entirely satisfactory slub-catchers had yet been evolved, even using the closest practicable setting, and at the other were yarns which were passed through so-called clearers so carelessly set or so inefficient that the term "clearing" became a misnomer. A yarn containing an excessive number of slubs compared with previous deliveries would result in a reduction in winding operatives' output and wages (not to mention complaints from the operatives), and would, in this event, lead to complaints and possible rejection of the yarn—always assuming correct settings and efficient slub-catchers. On the other hand, the slub-catcher on the ring frame enabled the spinner to detect the faults almost as they arose and to take remedial measures in time.

Mr. D. R. Christie, Galashiels, suggested, with reference to the No. 50 cheese winding machine, that it was found that the tension device imposed a severe strain of the yarn. On fine Saxony yarns, in particular, the increased stretch resulting therefrom was not a desirable feature.

Replying, the lecturer said that the degree of tension applied to a yarn was, of course, quite distinct from the setting of the slub-catcher, and could be varied over a wide range, providing a very hard package was not required. A close-set slub-catcher, providing it was correctly positioned in relation to the passage of the yarn, should not appreciably increase the yarn tension. There was, of course, the possibility of local stretch occurring when a slub was pulled through the slub-catcher without breaking the yarn, and this was more likely to take place where good quality yarn of high extensibility was being processed. They had another method of detecting slubs, however, which did not impose this strain on the yarn. This was known as the "Slub Trap", and operated as follows— Instead of a slit through which the slub was pulled, a movable detector was employed which responded readily to variations in the thickness of the yarn, and thus acted as a slub detector. The movement was transmitted through mechanism and stopped the winding spindle when any slub above a predetermined size reached the detector. In many cases the slub could then be picked off the yarn by the operative, and the spindle restarted without any knot having been tied. This method not only minimised the risk of yarn strain and stretch, but also removed slubs without substituting knots.

MODERN FABRIC STRUCTURES IN THE SCOTTISH WOOLLEN TRADE

By D. R. Christie, A.T.I.
(Peter Anderson Ltd., Galashiels)

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DISCUSSION

Mr. J. G. Williams, London, said he would like to inquire whether the lecturer had any remarks to make on the subject of the durability of Lastex fabrics. It was, of course, well known that sunlight very rapidly perished rubber. He had made an exposure of a Lastex tweed fabric and after exposure to sunlight (under Vita glass) he removed the Lastex yarns and tested the rubber core. In the one exposure made the rubber could be regarded as having perished after 20 hours of sunshine. This period could be experienced in less than a week of summer holiday. One could not draw conclusions from one exposure test, but the result was, at least, disquieting and he hoped that before going into the manufacture of these fabrics some experiments had been made.

Mr. Christie replied that the rubber core of the Lastex yarn was well protected from sunlight by several covering yarns. Fabrics containing Lastex yarns had been subjected to the scouring, dyeing, and milling processes as applied to all wool tweeds without showing any deterioration of the rubber.

Professor W. Davis, Nottingham, inquired how the border and the pattern were kept distinct and separate in scarf patterns. In discussing the effect of light on rubber threads, Professor Davis pointed out that such a point was of minor importance as the rubber core was completely obscured by six covering yarns and was never exposed to light in any form. Those interested in Lastex were concerned about the reports which would be given of such goods after two seasons use. There was a tendency towards deterioration of the rubber after frequent washings if the goods were dried off in hot cupboards or enclosed spaces. The maker-up of fabrics containing rubber cores found that the stretched rubber crept inwards on cutting the edges; also when sewing and seaming the needle pierced the threads and weakened them, unless the seam was made along the lines between the rubber threads.

Replying to Professor Davis, the lecturer pointed out that if the different effects in the border and ground were due to colour patterns only on a simple weave then the picking chain was usually arranged so that a handshift would give the desired change from ground to border and vice versa. In some cases where there were only very few picks per inch, the complete picking chain was used. If a fancy weave effect was required on the border it was advisable to arrange this so that it would be developed by a simple colour pattern, *e.g.* one-and-one weft for the border and obscured by another order of wefting for the ground. By this method of weaving, changes of pegging plans were avoided.

Mr. A. Lomax, Bolton, said that with regard to the use of dyed mercerised yarns for striping of suitings etc., the manufacturer insisted upon exact matching of shade. No deviation from the standard, however slight, was accepted. Could Mr. Christie say why such exactitude was necessary. His experience was that the matching must be absolute or it would be rejected.

To Mr. Lomax the lecturer said that the manufacturer had to satisfy the merchant and the slightest fault might result in pieces being rejected. Frequently mercerised cotton "fancies" had to replace the silk "fancies" used in the original samples and this greatly increased the difficulties of the dyer in securing an exact match.

Mr. H. B. Taylor, Carlisle, questioned Mr. Christie *re* types of wools used and settings for Scotch Tapestries. Were they entirely Scotch both in growth and production, or were they used along with other wools and yarns ?

Replying to the question Mr. Christie said that for upholstery fabrics New Zealand crossbred wools had proved to be very suitable either when used alone or blended with Cheviot wool. To produce a hard wearing fabric the yarn was spun to fairly fine counts and then doubled with hard twist. Fabrics for curtains etc., were made in a wider range of wool qualities and included practically all types of tweed yarns.

Dr. W. Hubball, Manchester, referred to the difficulties which confronted the manufacturer in the use of Lastex yarn. The problems would seem to lie chiefly in reconciling the different yarn elasticities in order to achieve various effects in the cloth, and there was a need for information on this special point. The samples presented suggested that the lecturer must have had experience of considerable experimental work in this respect, and any information of such work he could give would be very much appreciated.

Lastex yarn, said the lecturer, was obtainable with different degrees of elasticity and the effects were varied by adjusting the drag at the shuttle. For crinkled and crêpon cloths the effects were most pronounced with the yarns having the greater degree of elasticity and when the maximum drag was applied. If only one type of Lastex yarn were used the effects were varied by altering the drag at the shuttle and also by twisting the Lastex with a woollen or worsted yarn. By the latter method the tension on the Lastex yarn was controlled during twisting so as to yield a range of twist yarns of different degrees of elasticity These were then woven into the cloth in the same way as ordinary yarns.

SOME NEW POSSIBILITIES IN FANCY COLOUR AND WEAVE EFFECTS

By Professor A. T. King, B.Sc., F.I.C.

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DISCUSSION

Professor W. Davis, Nottingham, stated that there were serious practical difficulties in getting spinners to render wool and yarn unshrinkable as this involved staff, equipment, and practical skill which at present belonged to dyeing and finishing departments. When wool was rendered unshrinkable in pre-fabric form it restricted the finisher as he could not obtain the denser and fuller fabrics he desired; they remained comparatively loose and open. The felting power of wool was indispensable to most types of finish in woollen fabrics.

Replying to the foregoing speaker, Professor King said that spinners, unless they wished to put down their own equipment, would merely undertake the spinning, as they would with dyed tops. Genuinely unshrinkable yarn had not, hitherto, been available for hosiery fabrication. It gave a clean and distinctive unshrinkable finish in extra lightweight fabric, which was not producible from wool in any other way. For the denser fabrics the new process could be applied after milling. Ordinary chlorination before milling gave neither the one finish nor the other. As Professor Davies said, it was unsatisfactory. He agreed that hitherto the felting power of wool had been regarded as indispensable to most types of finish in woollen fabrics, but we were looking for new types of finish.

Mr. H. Busfield, Leeds, asked the following questions—

(1) What effect had the modified type of chlorination on the spinning properties of wool ?

(2) Were wools, tops, or yarns, preferred in a clean scoured state rather than in oil for subjecting to this chemical process ?

In reply to these question the lecturer said—

(1) Spun on the ordinary routine, the first impression might be that the treated wool spun less efficiently, but with the proper conditions appreciated, they had obtained consistently better spinning. For the same count and strength of yarn they had had up to 30% less twist with the treated wool. For woollen yarn, they had repeatedly gone to considerably finer skeins than could be got with the ordinary wool.

(2) The material was definitely preferred in the clean scoured state as any oil present would be made more resistant to scouring.

Dr. A. W. Stevenson, Galashiels, welcomed an addition to the methods already in use for producing effects by differential dyeing and differential shrinkage. The latter type of effect had in the past been limited in wool fabrics to the results of varying qualities and twists, both of which altered the handle of the material. The new method would have the advantage of giving virtually the same handle in the different parts. Now that attention had been drawn afresh to the possibilities of differential shrinkage he thought there was scope for a modification of the Bliss process of treating yarns. If, instead of the final steaming to set the yarns, they were air-dried in the stretched condition, they would weave at the stretched length and shrink early in the scouring process. Both yarns would shrink in the normal way during finishing, but in addition the treated yarn would shrink by an amount which could be predetermined with considerable precision.

Professor King believed the application of stretched yarn suggested by Dr. Stevenson was already being made, to produce crêpe effects, and he certainly agreed with him that this method could be further explored. The effects would, however, differ from those obtained by the method he had described, in that the whole fabric would be subject to felting and the embossed effect would tend to blur, and there would be negligible possibilities of differential dyeing.

Mr. W. W. L. Lishman, Todmorden, asked if any difference would arise in finish, if by carelessness on the part of an operative the bobbins were mixed. A risk existed here which should be guarded against.

To this question the lecturer replied that there would, of course, be this risk. It would be guarded against by tinting, or winding on differently coloured bobbins, as would be done, for example, with right- and left-hand twist yarns.

Mr. E. West, Leeds, raised the query as to whether any difference would be noticed by the hosiery knitters in the application of their winding emulsion (or "lather" as it was called) to these worsted yarns which had been produced on the new unshrinkable process. The point was whether the processing would in any way retard the absorption of the emulsion by the wool, as this would, of course, create certain later difficulties in knitting.

In reply to Mr. West, Professor King said that the yarn would wet out more easily and probably more evenly than ordinary yarn, and would tend to pick up more emulsion rather than less.

WARP-LOOM KNITTED FABRICS

By W. Davis, M.A.
(University College, Nottingham)

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DISCUSSION

Dr. T. Oliver, Galashiels, inquired as to the cost of the equipment; to which the lecturer replied that although machines to make all the fabrics exhibited would be costly, a start could be made on a restricted range of goods at a very reasonable figure.

Dr. E. Honneger, Zurich, said that Professor Davis had shown samples of warp-loom knitted fabrics, which, after finishing, had quite the same appearance as woven cloth for coatings. The lecturer would oblige if he would give an indication of the cost of manufacture of a warp-loom knitted fabric and of a corresponding woven fabric, assuming both to have the same weight per unit area and to be made of the same fibres.

Mr. T. A. Purt, Leicester, suggested that if Professor Davis would furnish particulars as to the warp knitting loom (courses per minute), comparison could then be made with ordinary loom speed (picks per minute). He also suggested that shrinkage in the finishing of a knitted woollen fabric to give woven cloth effect, was too excessive to place it on competitive basis with genuine cloth produced on the loom.

Mr. J. H. Lester, Manchester, in agreement with Professor Davis doubted whether a reasonable basis of comparison could be found as between the cost of woven and knitted fabrics. If the yarns used and the weights of the fabrics were the same, their characters would be so different that they could not be used for the same purpose.

In a general reply, Professor Davis said that the attempts to imitate woollen and cotton fabrics on the warp loom had not been successful. For example, in the case of warp loom fabrics milled to produce a woven cloth effect, it was necessary to use botany types of wool to obtain adequate felting power, which rendered the cost higher in relation to similar woven goods. The special characteristics of warp loom knitted fabrics had commended themselves to an increasingly large public on their own merits and exact comparisons could not usefully be made.

MODERN KNITTING STITCHES

By John Chamberlain, F.T.I.
(Colleges of Art and Technology, Leicester)

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DISCUSSION

Professor F. Bradbury, Belfast, asked Mr. Chamberlain if the Jacquard machine to which he had frequently referred, had many points of similarity in principle with the Jacquard machine as used in figure weaving.

The lecturer, answering Professor Bradbury, said the term Jacquard had been applied very generally to many types of selecting mechanisms. On straight-bar machines, and warp-knitting machines the ordinary cards, as used on weaving looms, had been in use for many years, but there was a difficulty in applying a similar system to circular machines. In the Shaw machine, about 1880, steel plates with holes were used to select the needles for producing heels and toes. The patent of the Jacquard Knitting Machine Co., U.S.A. in 1923, however, was the first to claim for a paper or thin light element operating for needle selection and this patent had been sustained. Other methods employed ribbons or tapes, grids, and cards, pegged drums, multiple discs and these devices were known as "jacquards". The jacquard card selection was also used for timing and controlling purposes.

Mr. W. H. Slater, Manchester, extended a word of compliment to the ingenuity shown by the speaker, and the individuality of Midland hosiery machine manufacturers in the development of the 1934 ladderproof fabrics. Mr. Slater said Leicester hosiery, as a result of the above ingenuity and individuality, had become a bright spot as an outlet to otherwise troubled spinners.

Mr. Chamberlain, replying, said the enterprise of the machine builders in the Midlands, especially in Leicester, had been rewarded by increased sales of machines at home and abroad. The resulting machines had benefited, primarily, the British hosiery trade, but other countries were now purchasing heavily. Nevertheless improvements in machinery must necessarily benefit the country of origin and finality had by no means been reached. Several hosiery machine builders spent large sums of money each year on experimenting and research.

In discussing knitted fabrics into which weft threads were laid, Professor W. Davis, Nottingham, gave some details of the Hill loom in which a warp was used, each thread having a guide which lapped always over the same needle. Behind the needles was a frame, over which the weft threads were laid by a traversing bobbin. This frame racked round at every course and laid its thread straight between the needles and the warp threads at one movement. Such fabrics were extremely firm in handle.

The lecturer commented that straight weft threads had been introduced into warp knitted fabrics for many years and it was interesting to recall that the chairman, Mr. J. H. Lester, carried out, in conjunction with a Leicester inventor, a series of experiments concerned with warp chains and straight weft nearly 20 years ago. Many designs were now being produced on the ordinary Raschel machines by these means.

FABRIC STRUCTURE AND LAUNDERABILITY

By R. E. V. Hampson, D.Sc.
(Director of the British Launderers' Research Association)

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DISCUSSION

With reference to the stripe effect in certain damask fabrics, Mr. W. H. Slater, Manchester, pointed out that a probable cause might be the failure to bind correctly the weave structure where the satin and sateen interchanged to produce the figure effect.

Mr. W. W. L. Lishman, Todmorden, asked whether articles received for the first time at the laundry containing size or starch, were desized before laundering, especially those of fine weave ? Because, if not, heavily sized goods in the presence of a lime soap might develop white marks as such deposits would not allow these substances to pass easily through the goods being washed.

Mr. W. Kershaw, Manchester, confirmed Dr. Hampson's statement that goods during laundering tended to conform to the original folds, which are unavoidable in all materials processed in the rope form. It is therefore necessary in certain types of heavy goods, to carry out the operations of scouring etc., in the open width.

Mr. J. G. Williams, London, said that with reference to Mr. Lishman's remarks on streaks on laundered fabrics being due to lime soaps, it was his experience that in a number of cases the colour had not penetrated the fibres properly and so the result of slight surface wear was to cause light coloured or white streaks. The resistance of the dyed fabric to wear of this type could be tested by folding over the cloth to make a tuck and then scrubbing over this fold using a moderately stiff nail-brush and very soapy water. It had also been his experience that the colour fastness of coloured sheets to laundering was sometimes low. Long before the sheet was worn out the colour had practically all left the fabric. This applied to vat dyed sheets and, in the cases he had examined, the wash rubbing test he had given had not shown any pronounced loss of colour. He thought that consideration should be given to the launderability of coloured sheets or the public demand for them would be affected. With regard to fabric structure he had found some rayon slub repp furnishings so loosely constructed that thread slippage occurred in the fabric even with careful laundering. Slippage could easily be measured and it would be well if the maximum safe limit could be defined.

In reply to the various points raised by members in discussion, Dr. Hampson agreed that incorrect binding of the weave at a satin-sateen interchange could account for the line of wear which arises in certain instances. On the other hand there were undoubtedly cases in which failure could not be attributed to this fault.

So far as the laundry treatment of new articles was concerned it was not usual to give any specific desizing treatment apart from the ordinary washing process. The difficulties suggested in this connection did not normally arise, and it would therefore appear unnecessary to make recommendations for preliminary desizing treatments.

The British Launderers' Research Association had examined numerous fabrics similar to those referred to by the last speaker. The facilities they possessed for examining such fabrics under well-controlled commercial laundering conditions were of very considerable assistance in estimating suitability for laundering.

LACE FABRICS

By G. H. Buckley, F.T.I.

(University College, Nottingham)

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DISCUSSION

Mr. G. H. Thompson, Oldham, said that laces had always delighted ladies. Had the lecturer amongst his samples an example of the fabric known as "Angel Skin" ? He did not know whether it was the diaphanous material that artists clothed angels in ! Perhaps Mr. Buckley could explain ?

An effective design, replied Mr. Buckley, was worked in with a groundwork composed of the finest silk, and was of a material having a different affinity for dyestuffs. The cross-dyed effect was such as to give the design an ethereal aspect. Owing to the generosity of Messrs. Flersheim & Co. Ltd., of Nottingham, a number of flouncings of "Angel Skin" were available for inspection.

In discussing the types of yarn used in lace manufacture, Professor W. Davis, Nottingham, stated that the finest cotton yarns spun in this or any country were used in lace, 400's single cotton counts being taken for this work. These worked well on the lace machine and could be justly regarded as a marvellous production of the British spinner.

The finest yarns, said the lecturer, and the highest quality in all counts, were a distinct feature in the remarkable range of laces loaned by Messrs. Birkin & Co. Ltd., of Nottingham. The perfectly regular net ground could be marred by an uneven thread.

Mr. J. Chamberlain, Leicester, asked whether one set of threads was known as "wefts". He said that at a meeting of the Leicester Textile Society he had been criticised for calling one series of threads "warps": these were subject to a definite lateral movement and it had been suggested that "wefts" was a more suitable term. He also asked how "the floats were cut out and whether the net ground in the production of fancy trimmings was burnt or dissolved away".

Mr. Buckley replied that the term "weft" was not used in the twisted lace industry. Portions of some laces were sometimes described as having the appearance of warp and weft. The weft thus described, however, could be produced either by the bobbin or the warp. The "floats" occurring in the piece of lace exhibited were cut by hand, and were a neater finish than were laces which had been machine cut. The whole purpose of a ground in burnt-out laces, was to give maximum support to the embroidery thread, and to allow of its being easily destroyed without affecting the design. Maximum support would not be achieved by employing a net ground.

PREPARATION OF HARD-TWISTED YARNS FOR CRÊPES

By J. W. Pennington, F.T.I.
(Technical College, Burnley)

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DISCUSSION

Mr. A. Lomax, Bolton, said, in regard to the matter of "setting" the twist (overcoming the springiness of crêpe yarns), that this could be achieved by mercerising the yarn. Large quantities of crêpe yarns have been mercerised by his firm.

The lecturer, in reply, stated that mercerising was a much more expensive process and he did not think such yarns compared with a crêpe yarn prepared with a good size mixture.

Mr. G. H. Thompson, Oldham, asked if crêpe yarns were properly prepared, that is reverse wound, in some cases pre-treated before twisting, and the yarn set after twisting, it would appear that steaming or baking by the manufacturer was unnecessary.

Mr. Pennington answered that if properly prepared and the twist set by a good size preparation and steamed afterwards there should be no need for the manufacturer to adopt steaming or baking to kill the twist before weaving.

Mr. A. E. Delph, Bocking, expressed his agreement with the author of this paper that a difference of 10% above and below the mean twist for rayon crêpe yarns would produce defects in the finished fabric. Such defects were chiefly in the nature of weft bars of uneven contraction and weft bars of irregular figure. He said he considered it preferable to reverse the direction of pirning in one twist so that in the case of both right and left twists the effect of the yarn running off the nose of the pirn was to take twist out rather than to insert further turns. Although where reverse pirning was not adopted the extra twist inserted was only small, such twist was unset and tended to make the yarn lively and liable to snarl.

The lecturer expressed his agreement with what Mr. Delph said.

THE PROCESSING AND WEAVING OF RAYON YARNS

with an Introduction on the Effects of Moisture Content on their Physical Properties and an Appendix of Some Typical Faults in Fabrics

By A. E. Delph, LL.B., B.Sc.
(Courtaulds Ltd.)

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DISCUSSION

Mr. W. Young, Kilbirnie, asked if two beams were made—(1) a beam of lubricated rayon and (2) a beam of ordinary bleached rayon, would the amount of stretch be the same if both beams were subjected to similar tensioning in winding, warping, and sizing. Or would the effect of the lubrication help to lessen the amount of stretch in that yarn.

Mr. Delph said that lubrication has little or no effect on the stretch of these yarns.

Mr. F. Chadwick, Preston, inquired if Mr. Delph could say whether percentage of humidity was more important than moisture content in the winding and weaving of rayon yarns, *i.e.* would it be preferable to work to a definite percentage of moisture or to a definite amount of moisture as represented by grams of moisture per cubic foot in the atmosphere during the winding and weaving processes ?

Mr. Delph replied to the effect that it was the actual moisture content of the yarn at the time of processing which determined its extensibility and, the only sure means of securing a proper and constant condition of the yarn in this respect, was to adequately condition in an atmosphere of constant relative humidity. Working to a constant moisture content of the atmosphere would not do, as the same moisture content might represent a low relative humidity in a warm atmosphere and a high and unsuitable relative humidity at a lower temperature.

Mr. J. Hollas, Preston, pointed out that the lecturer had dealt with the setting of twist in Viscose rayon. Manufacturers often had to steam or to bake viscose crêpe weft to make it weave satisfactorily. Would the lecturer say that it should not be necessary for the manufacturer to either steam, bake, or otherwise treat the yarn before weaving ?

Replying to this question the lecturer said that a well "set" viscose crêpe yarn should require no further setting for the weaver's use, but the setting might be disturbed by pirning under too much tension, in which case the yarn might become too lively, or considerable changes in the relative humidity of the atmosphere during storage might tend to cause the yarn to slough off the pirn during weaving, in such cases the yarn required a further slight steaming, which eradicated the trouble.

Mr. A. W. Bayes, Hyde, said that the lecturer had given graphs of the relationships between moisture regain and rayon strength and extension to prove the need for constant humidity, could he give similar information on the temperature-strength and extension relationships ? Was there any necessity, apart from the comfort of the operative, to keep the room temperature as low as 60° F.

Mr. Delph's reply was that an increase in temperature had but a small effect upon strength and extensibility compared with the effects which might occur with increase in relative humidity. As far as the author was aware, there had not been so much work done on the temperature effect as on the relative humidity effect, probably because the effect was nearly negligible. Measurements on temperature effect of viscose yarn conditioned in a comparatively dry atmosphere of 42% in each case had shown that the extension of 150/21 viscose yarn under a load of 75 gms. (*i.e.* ½ gm. per denier) had only increased the extensibility from ·8% to ·9% for an increase in temperature of 20° F. from 60° F. to 80° F. This was a much higher tension than occurred in good processing and hence the effect might be considered negligible in general practice. Mr. Bayes' suggested temperature of 60° F. was on the low side and his processing would be perfectly safe at 70° F. provided he maintained a constant relative humidity of about 60° F.

Mr. A. Scholes, Liverpool, said that his own observations of fluctuations in relative humidity were similar to Mr. Delph's. He pointed out that the omission of daily recordings such as these were often more important than weekly figures. Mr. Scholes did not agree that milky stripes were produced entirely by the loom, but were undoubtedly so caused in most cases. The occurrence of milky stripes in sectional formation points back to the warping or the yarn being responsible, although the actual operation of weaving may be the factor which makes them visible. In view of this, Mr. Scholes asked what was the real factor which produced them, and why they had developed comparatively recently.

In reply to Mr. Scholes, the author said he agreed that daily records of relative humidity were of importance as high fluctuations through the day or night were likely to be detrimental to either good processing or good weaving. Mr. Delph recommended the keeping of autographic combined records of temperature and relative humidity which showed the effects continuously and exhibited examples of continuous records which require changing only once a week. It was from a year's collection of such records that Fig. 1 in the paper was prepared.

When warp stripes, continued Mr. Delph, milky or of the other description, occurred in sectional formation corresponding with the runs in warping, it was safe to say that the defect was due to either the yarn or the warping. In the case of milky stripes which did not occur in warp runs, these were produced in the loom and generally shifted their position when either healds or reeds were reversed. They were due to friction in the loom and it was in such cases that lubricating rods might be helpful. If Mr. Scholes had experienced more trouble recently with milky stripes of this latter description, it might be due to the fact that much lighter sizings were used to-day than in the earlier days of the rayon industry. and greater perfection was looked for in to-day's fabric.

Discussing the point by Mr. Fletcher Chadwick, Mr. F. D. Farrow, Didsbury, suggested that the atmospheric factor influencing the behaviour of textile materials was the relative humidity rather than moisture content of the air. If it should prove impossible to maintain the temperature at a desired standard it would be advisable to work to a constant relative humidity rather than at a constant number of grams of moisture per cubic foot. In weaving cotton the difficulty arising in the early morning was a high warp breakage rate caused by the abnormally low relative humidities often experienced in weaving sheds at that time. It was commonly stated that refrigeration was essential for controlling humidity at moderate values on all working days. Was it not possible that silica gel employed for drying air for use in blast furnaces might also be employed in plants for control of humidity in the textile industries ?

. In weaving sheds where no humidity control was used, said Mr. Delph, it was his experience that high humidities more generally obtained in the morning due to temperature fall during the night, particularly in the winter months, and weaving difficulties with rayon warps in the early hours of the day often had been avoided by maintaining the temperature during the night, thus securing more even relative humidity conditions. He had no experience with the use of silica gel for extracting moisture from the atmosphere on a commercial scale, it might certainly be employed as an alternative to costly refrigeration if it showed an advantage as far as capital outlay, maintenance, and running costs were concerned.

Mr. A. Glover, Bolton, said that probably one of the most important points raised was that of milky stripes in rayon fabrics. These milky stripes were caused by friction to the yarn during weaving, and everything should be done to minimise this friction during weaving. It had been found that lubricating the rayon yarn by rollers (composed chiefly of soap and wax) was beneficial. These rollers should be so applied that each warp end got (as nearly as possible) the same amount of lubrication. It was also advisable not to apply too much of this lubrication to the rayon yarn. If the yarn was to be lubricated it should be done before it reached the healds.

Mr. Delph said he was in agreement with all Mr. Glover had said, but would like to emphasise that great care should be used in the selection of a lubricant which was readily removed in the scouring process, and did not saponify acetate yarns.

The data in this paper, said Mr. J. G. Williams, London, explained a trouble being met with in all-rayon fabrics in wear, more especially with crêpe weft fabrics. If the garments were other than loose fitting, then tensions occurred with bodily movements and with muscle expansions etc., and permanent extension of the yarns occurred. This showed as cockling of the fabric which could not be cured by hot-ironing. The fact that the elastic limit was much lower at high humidities explained why this cockling occurred under the arm-pits. Probably the other sites of the cockling (across the shoulders and in the fore-arm portion of close fitting sleeves) were regions of moisture condensation when garments were worn over frocks as well as regions most exposed to stresses in use.

As this trouble could occur after only one or two periods of wear, he continued, it was naturally very irritating to the customer. He had advised all departments of the Stores with which he was associated that where possible they should see that frocks sold were free fitting. This, however, could not always be observed as goods were sold at present in ready-made sizes and with customers just holding the frock to the figure to see if it were the right size. It would probably be to the interest of all parties if some of the picks were cotton yarns. Otherwise one might find fabrics of this type getting a bad name with the retail buyers and with customers and the consumption would be affected as it had been with rayon furnishing fabrics owing to the use of unsuitable vat dyes.

The author replied that he had only seen examples of cockling as described by Mr. Williams in the case of fabrics prone to slip. Cockling might then occur particularly under the armpits due to excessive stretching where the fabric had become damp from perspiration. He agreed that frocks ought not to be too tight a fit where they were liable to take the strain and at the same time got damp from perspiration, and it was good policy also to draw the attention of the "makers-up" to this point, particularly with the cheaper class of rayon fabrics.

He was doubtful whether Mr. Williams' suggestion of introducing some picks of cotton into a rayon crêpe would overcome the trouble, but their introduction would certainly alter both the appearance and character of the fabric and would present finishing difficulties in rayon crêpe fabrics.

If the wholesale buyer preferred a cheaper quality, said Mr. Delph, simply on account of the price factor, he usually got a lower grade of fabric containing less yarn, and he could not expect the same strength as with a better quality. Although the question of dyeing rayon fabric was outside the scope of this paper, as Mr. Williams had referred to the use of unsuitable vat dyes on furnishing fabrics, the writer referred to the fact that Courtaulds Limited and also some of the dye manufacturers had published lists of suitable dyes for the casement trade.

SOME OBSERVATIONS ON FABRIC STRENGTH IN RELATION TO YARN PROPERTIES AND DENSITY OF STRUCTURE

By W. E. Morton, M.Sc.Tech., F.T.I.
(College of Technology, Manchester)

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DISCUSSION

Mr. A. W. Bayes, Hyde, said as it was impracticable to do research in each of all the possible fabrics, it was therefore most important that a systematic method of visualising the structure of fabrics should be developed. What were the lecturer's views on this point?

Reverting to the lecturer's statement that textile yarns were weakened by bending, Professor F. Bradbury, Belfast, emphasised the fact that this relative decrease in load resistance, incidentally, constituted a chief contributory factor in a fabric's strength. For, without any increase in angle of curvature, a correspondingly heavier cloth and a greater load and moisture resistance could not be produced, with the same yarns and weave. For example, given warp and weft yarns each having a diameter of 1/60th of an inch, then a plain cloth woven on the "square" would contain approximately 30 diameters of warp and 30 diameters of weft. But if the warp yarn was "set" full up to its diameter, it would bend to its maximum and the cloth would then approximately contain 60 diameters of warp and 30 diameters of weft per inch. Professor Bradbury also assumed that as yarns could not be tested in a curved state, except in the woven fabric, the modification of strength is not alone dependent on bending, but on many other debatable and technical weaving factors.

Mr. J. H. Strong, Blackburn, asked that, if in testing fabrics for strength, any regard was paid to the feel and appearance of the cloth, which in the great majority of fabrics is of far greater importance than strength.

In reply to Mr. Bayes and Mr. Strong, Professor Morton stated that in his paper he was concerned solely with the question of strength and for that matter with only one or two of the factors which affected that property. Having regard to the complexity of any single fabric structure, and to the very large number of different structures that were met with in fabric form, not to mention the incompatibility of some of the desirable fabric properties, it was clear that a complete system of correctly weighted laws of structure was not yet even in sight. Meantime it was necessary to prepare the ground by piecemeal experiment.

THE STRUCTURE OF MODERN FABRICS*

By J. Read, F.T.I.
(Royal Technical College, Salford)

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DISCUSSION

The lecturer had stated, said Mr. J. Hollas, Preston, that his tests of de-twisted yarn showed it to be stronger than yarn with normal turns. He asked whether the comparison was in respect of yarns spun from the same cotton. The de-twisted weft was probably made from super-combed Sakel, whereas the other weft may be Uppers combed.

Mr. Read said the yarns were not spun from the same cotton. As stated, the de-twisted yarn was merely substituted for a good commercial yarn of equal count. No attempt was made to compare the structure of the two yarns with respect to quality of cotton used.

Mr. W. Wilkinson, Blackburn, also referred to Mr. Hollas' statement that the comparison of no-twist yarn of 24's count was not fair, when the twistless yarn was produced from good Sakel cotton and the ordinary yarn from ordinary American. He said that he had made tests with all factors except twist (per inch) the same, and with 9 turns per inch in one yarn and no turns in another. He found a very similar state to that given by the lecturer.

Professor F. Bradbury, Belfast, complimented the lecturer on the large variety of examples of beautiful woven fabrics submitted. The outstanding and interesting features of the lecture were the references to, and the examples of, cloths where beauty and ornamental value had been attained perhaps at the sacrifice of durability. Mr. Bradbury expressed the opinion that too much stress had, hitherto, been laid on strength and durability of yarns and fabrics and said "It is not desirable that all woven fabrics should be made to resist the maximum wear and tear. It is far more important from the manufacturers' and dealers' point of view to produce fabrics, where design, colour, softness in handle and draping properties are manifest characteristics, even though the structure may be inferior in strength and durability as compared with normal standards. Such material generally outlives the period of fashion, increases the demand and costs less. What more is wanted ? Trade does not always go to the manufacturer who gives the greatest intrinsic value, nor yet to him who produces the lowest priced goods. It pays to produces novelties of design and colour which arrest the attention of customers".

Mr. J. F. Fletcher, Keighley, said there appeared to be two points of view. There was the man whose life depended on the strength of the tapes of an aeroplane parachute and on the other hand there was the woman who wanted soft dress goods which might only be required to wear for a few weeks. It was just as necessary to test for weakness in fabrics as strength. What was the limit for setting a cloth for slip ? The onus of fabrics which slipped was entirely with the manufacturer. Twist and size played a prominent part in some goods, *e.g.* marocains.

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* See "Corrigendum" on page P337 of this issue.

The lecturer agreed with Mr. Fletcher's remarks regarding the two points of view with respect to tests for strength etc., of a fabric. No general statement could be made regarding the limit for setting a cloth to avoid slippage of the yarns. So many factors were involved in the structure of any specific fabric, each of which was responsible for the holding of the yarns in their proper place. The lecturer suggested that a much more serious defect than that of slippage of yarns was the preserving of finished dimensions in a fabric after laundering. Most crêping fabrics were liable to distortion in laundering, and suggested that such fabrics should be sold as "fully shrunk", otherwise.

Mr. A. Glover, Bolton, advised teachers in technical schools and students to study the possibilities of fabrics made from yarns spun from Fibro. Fabrics made from this new type of yarn had a good feel and characteristics of their own. Moreover fabrics made from Fibro would be beneficial to the country in many ways. Firstly, the filaments of the yarn would be made in this country and so avoid importing raw cotton from abroad. The spinning, weaving, finishing, and other industries would also benefit.

The lecturer replied that although he had not dealt with this development in the paper submitted, he was aware of the new structures which would shortly come forward composed of yarns spun from Fibro.

Mr. W. Young, Kilbirnie, said the trend of modern design for furniture fabrics included weaves where the length of float was of value, particularly so where the figures were produced with warp floats of artificial silk. Sometimes one came across fabrics where no respect had been given to an average length of warp float which would be effective and suitable for the purpose and yet not too loose to become raggy or faulty in appearance. The designer and cloth constructor must know the utility of the cloth he was about to construct; whether the cloth were simply a hanging fabric, as a curtain, or an upholstery cloth, etc., and the length of float permissible to be made.

In reply to Mr. Young, Mr. Read said several members suggested that very often fabrics constructed for a special purpose were employed by the public for a second use for which the fabric was not suitable. For example, a casement fabric will not necessarily make a good cushion cover or upholstery cloth. The manufacturer was entirely in the hands of the consumer in these matters.

Mr. A. Anderson, Blackburn, said that in his opinion, there was ample scope for development. In the case of window casements these were subjected to severe criticism and the slightest imperfections of warp float or faulty matching of picks were quickly discernable. Fully automatic looms were now playing a prominent part in these productions.

The lecturer agreed with Mr. Anderson that the defects he named were very often seen in casements that were exposed to an illuminated background. These faults generally arose during the actual process of weaving, but the origin of the fault was hardly within the scope of the paper.

SOME EXPERIMENTS AND OBSERVATIONS IN CONNECTION WITH TWIST WINDING

By G. A. Bennett, M.Sc.Tech., M.A.(Com.), A.T.I.

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DISCUSSION

The chairman, Dr. F. T. Peirce, introducing the lecturer, said that no industry gave greater scope for mechanical ingenuity or for æsthetic taste than the textile industries, as was exemplified by other papers before the Conference. Modern science was also making it possible to explain and control the properties of the materials themselves and to make new ones. These activities were the more spectacular effects of scientific technology, but they upset the traditional methods and needed to be supplemented by a less exciting but more fundamental application of science—the critical, objective observation of processes to control them more precisely to the desired end and to eliminate unessential features introduced by the imperfection of mechanical means. Winding produced no spectacular results but could affect all later processes and the final quality of the product. It was typical of the processes which demanded all the refinement of systematic observation and statistical analysis, to determine the best conditions for quality and cost in mass production. The interest of such papers lay in the attitude and method rather than in the particular facts and ideas, for they represent a revolution in the control of technical processes.

At the conclusion of Mr. Bennett's remarks the chairman said that a critical analysis of the method of tension measurement demanded more time than was available, but he would recommend to the author a further consideration of the effects of friction in the device used.

Mr. G. H. Thompson, Oldham, said that a 34's twist yarn ought not to fail at 645 yards per minute. It was perhaps not good practice to wind at so high a speed, yet much higher speeds were accomplished on hosiery yarns which had not the same tensile strength as twist yarns.

Replying to Mr. Thompson, the lecturer said that the maximum speed at which a yarn might be wound, without breakages due to excessive tension in the yarn, varied greatly, and depended upon the conditions under which the yarn was being processed. The results of the measurements of yarn tension obtained by experiment No. 1 of his paper showed that a speed of 645 yards per minute was the maximum when a 34's twist yarn was wound under the conditions therein described. If, however, the yarn were taken from a supply bobbin of different diameter, or the path of the yarn from supply bobbin to warper's bobbin was such that there were fewer places at which there was friction between the yarn and the yarn guides, etc., then the yarn tension would have a different value and the maximum winding speed would accordingly differ.

Mr. F. D. Farrow, Didsbury, asked whether it was certain that the effect of friction at the point A (Fig. 2) could safely be neglected. The yarn tensions quoted in Table I appeared to be very high and it might be well to suspend judgment on their correctness as absolute values. They could safely be accepted as showing the variation of tension from start to finish or from tube to tube.

Mr. A. W. Bayes, Hyde, asked if, as a check on the estimated friction in the instrument, the lecturer had compared the low strength end of his single thread strength frequencies with the tensions at which breaks occurred in winding ?

Dr. A. W. Stevenson, Galashiels, pointed out that friction would have a very considerable effect in the apparatus shown in Fig. 2. The frictional force had a moment about F of 2 in., whereas the force being measured had a moment of approximately 0·2 in., so that should $\mu=0{\cdot}1$ the effect of friction on the reading would be equal to the effect of the force whose measurement had been affected.

In reply, Mr. Bennett said, to obtain absolute values of the yarn tensions it would be necessary to take into account the effect of friction at the measuring apparatus and at other points where the yarn made contact with the guides or the clearer. It was not possible, owing to lack of space between the clearer and the warper's bobbin, to measure the yarn tension at that point hence the effect of friction at certain points was neglected. He appreciated the fact that under certain circumstances the effect of friction at the points mentioned would be considerable. In an endeavour to compare the results obtained in actual practice with the results anticipated, a number of winding tests were subsequently made. Yarn breakages began to occur at approximately the winding speeds anticipated, but the weight of yarn wound during the tests was small.

SOME DEVELOPMENTS IN MACHINERY USED FOR WOVEN SMALLWARES

By W. Holt

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DISCUSSION

Mr. W. Wilkinson, Blackburn, said he was pleased that the subject of smallware weaving had been included in the list of lectures. The subject was not overlooked by the examining bodies because the City and Guilds of London Institute had an examination for Ribbon and Smallware Weaving. The new loom was an interesting feature of the lecture, and he asked for an explanation of the reed or comb.

Mr. Holt replied that the subject of smallware weaving was not an easy one to introduce to textile experts, because technically it was behind the rest of the trade. It had a large number of problems that would well repay investigation. The high-speed Saurer loom was certainly an interesting mechanism and the split reed was perhaps its most novel feature. A model of the reed was passed round to illustrate the description in the text.

Professor F. Bradbury, Belfast, stated that three points of advance in weaving mechanism had impressed him during Mr. Holt's lecture. These were (1) the invention and adoption of the curved shuttle which facilitated an increase in width of reed, without any increase in width of loom. (2) The use of positive picking which was ideal in principle because it eliminated many defects and neutralised the enormous consumption of power used in negative picking. But did this advantage outweigh the necessary increase in relative width of the loom ? (3) The adoption of the split reed as used in Saurer's exceptionally high-speed loom was a factor of tremendous importance to the weaving industry.

The lecturer agreed that the curved shuttle had certainly been instrumental in increasing the effective weaving space of smallware looms, and with improved methods of construction would no doubt become more widely used. It was not necessary to increase the relative width of loom with positive picking as applied to smallware looms. The relation between reed space and shuttle length was the same in both fly-shuttle and positive-shuttle looms.

Professor W. Davis, Nottingham, asked a question as to the present state of the ribbon industry in this country and inquired about the steps taken by manufacturers to obtain the most modern and efficient looms for this work. He stated that he understood that smallwares were now being made in a much wider range of colours and designs than formerly and this was proving a stimulus to the trade. Firms were engaging designers to impart to their productions new colours and effects to achieve season-to-season novelty.

At present, said Mr. Holt, there were signs of new life in the ribbon industry in this country. Manufacturers were demanding better machinery and were getting it. There was an increasing number of new weave and colour effects being used, as a result of the spread of technical education.

CORRIGENDUM

"THE STRUCTURE OF MODERN FABRICS"

By J. Read, F.T.I.

(Royal Technical College, Salford)

Corrections have been pointed out in this paper (pages P266–P284, June issue) as follow—

Fig. 2, page P280. Section B should be → and not as printed.

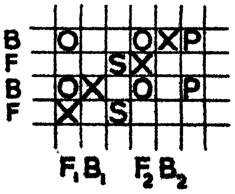

Fig. 2, page P280. Section C, the face ends should read F_2, P_1, F_1, P_2, S and not as printed.

NOTES AND NOTICES

National Certificates in Textiles

The announcement that the Board of Education have agreed to co-operate with the Textile Institute in the conduct of a scheme for the award of National Certificates in Textiles is a matter of considerable importance to all concerned with the technical training of part-time students belonging to the textile industry of this country. The Certificates will be issued jointly by the Institute and the Board on the successful completion of approved part-time courses, and the scheme may become operative in the Session 1934–35, provided applications from the Colleges and Schools are submitted and approved in accordance with the rules.

The aim of National Certificate schemes is to provide industry with a supply of well-trained men who have received training under qualified persons in well equipped institutions and who have given proof of their intelligence, perseverance, and attainment in a progressive course of part-time study. The schemes are framed and operated by professional institutions, representing industry, in close co-operation with the Board of Education, representing the colleges and schools. National Certificates are not awarded merely on examination results. They certify that the student has diligently followed a part-time course of training in approved conditions under qualified persons and has reached a standard of attainment satisfactory to the Professional Institution and the Board of Education.

The formulation of a scheme of National Certificates in Textiles was undertaken as a result of pressure from schools at which the success of National Certificates in Mechanical Engineering, Chemistry, Electrical Engineering, Building, and other subjects was evident.

In a preliminary report to the Council of the Textile Institute at the time when the question of framing a scheme for National Certificates was first considered, it was pointed out that the first effect of such a scheme would be to bring the various branches of textile instruction into line by demanding for all a reasonable mathematical and scientific content of the courses. This insistence upon mathematical and scientific instruction would tend to raise the general standard of textile instruction, and it was probable also, that when the various branches of textile instruction had been brought into line the time would be ripe for a more general treatment of textile technology than is now possible. Moreover, National Certificate procedure is intended to bring the technical colleges and schools into closer association with the professional institutions which represent those industries in which the students are engaged or are likely to be engaged and for which they are being trained. On the one hand, it enables the professional institutions to influence the training so that in character and standard it may meet the requirements of the industry and, on the other hand, it gives the students and the schools assurance and competent guidance in their work.

The late Alderman William Frost, J.P.

By the death of Alderman William Frost, J.P., which took place on the 10th July at his residence at Broken Cross, Macclesfield, at the age of 76 years, the Textile Institute has lost one of its most constant and esteemed supporters. Not only had he contributed substantially to the funds of the Institute, but he had given an enormous amount of voluntary service on the administrative side of the organisation, more particularly as Chairman of the Finance Committee for many years. Indeed, it has been largely due to his endeavours in husbanding the financial resources of the Institute, that the present position in regard to finance has been achieved. His father was the founder of the firm of Messrs. William Frost & Sons, silk throwsters, at Park Green Mills, Macclesfield, with which he was associated from 1873 to 1926. The late Mr. William Frost was in attendance at the Institute at Manchester only a week prior to his death and the announcement of his passing came as a great shock to friends he had so recently met. For a considerable number of years he served in the capacity of Honorary Secretary, in addition to fulfilling the duties of Chairman of the Finance Committee. In 1930, he was awarded the Institute Medal in recognition of his services to the Institute and to the textile industry. In latter years, Mr. Frost had devoted his energies almost entirely to local government and other forms of public service. He was Mayor of Macclesfield in 1910—Coronation year.

Institute Membership

At the July meeting of the Council, the following were elected to membership of the Institute: Ordinary—C. E. Lomax, 2 Laneside Road, East Didsbury, Manchester (Representative for Great Britain for Melliand Textilberichte, etc. and Manufacturer's Agent); H. W. McGregor, 27 Waymouth Street, Adelaide, S. Australia (Director, J. W. McGregor & Sons Ltd.); G. Parkes, Southcroft, Wilmslow, Cheshire (Director, Small & Parkes Ltd., Hendham Vale Works); J. H. Smith, Hukumchand Jute Mills, Naihati P.O., E. B. Railway, Bengal, India (General supervision work). *Junior*—A. H. Beverley, Craig-Owen, Ravensthorpe, Dewsbury (Student, Leeds University); W. Jockers, Schiltach, Schwarzwald, Germany (Student); W. Siegel, Poessneck i/Thur, Hohe Strasse 45, Germany (Student); F. Thornton, 63 Rufford Street, Bradford, Yorkshire (Trainee, Henry Mason (Shipley) Ltd.). *Life Membership*—B. de la Torre, P.O. Box 83, Cuzco, Peru, S. America (Technical Director ot Lucre Woollen Mills).

Honorary Fellowship Award

At the July meeting of the Council of the Institute, it was unanimously decided that the Honorary Fellowship of the Institute be conferred upon Mr. C. F. Topham, of Messrs. Courtaulds Ltd., Coventry, in recognition of his distinguished services to the textile industry, and particularly in regard to his invention of the "centrifugal" spinning box in connection with the production of artificial silk, an achievement which, together with Mr. Topham's discovery of the "ageing" process, formed a decisive factor in production on a commercial scale. The Honorary Fellowship is the highest award which the Institute confers and only three previous awards are registered—Mr. C. F. Cross, inventor in relation to the viscose artificial silk process; the late Mr. Horace Lowe, inventor in relation to the mercerisation of cotton; and Mr. J. W. Nasmith, inventor of the Nasmith Comber. It is intended that the award to Mr. C. F. Topham shall be formally presented at a meeting of the Midlands Section of the Institute at Leicester later in the present year.

Institute Premises—Closing for Holidays

Members are asked to note that the Institute premises at 16 St. Mary's Parsonage, Manchester, will be closed during August Bank Holiday week. The period covered is from noon, Saturday, 4th August, to 9 a.m. Monday, 13th August.

INQUIRIES

An inquiry thought to be of general interest is, with the permission of those concerned, published hereunder. Further contributions from members would be welcomed and should be addressed to the Editor.

Inquiry *re* Cotton Doubling

To the Information Bureau Textile Institute

I should greatly appreciate assistance on three points in connection with cotton doubling. The points are—

(1) *Balanced Twist.* What is it and what use is it in practice ?

(2) Maximum turns per inch in 2-fold yarns before the yarn becomes weaker.

(3) Maximum strength of doubled yarn. Is it obtained by slow speed and heavy travellers ?

With reference to (1) I rather doubt if there is a definition of balanced twist in 2-fold yarn, that is satisfactory to all interested in cotton yarn doubling. In any case, the usefulness of a definition seems very limited. One common definition of balanced twist in 2-fold yarn is half the amount of twist in doubled yarn and in the opposite direction compared with the twist in the single yarns employed. For example, if 64's doubling twist yarn had $\sqrt{64} \times 3{\cdot}25 = 26$ turns per inch in the positive direction (right-hand twist), the 2-fold 64's would require 13 turns per inch in the opposite direction, the twist co-efficient in this case being $13 \div \sqrt{32} = 2{\cdot}3$. Such a 2-fold yarn will have 13 turns per inch left in each of the two single yarns, thus the amount of twist in the doubled yarn is said to balance the amount of twist left in each of the two single yarns. Each turn of negative twist in the doubled yarn removes one turn of positive twist from each of the single yarns. Such a 2-fold yarn would be soft, loose, and lustrous.

Another definition of balanced twist is that the doubled-yarn twist in the opposite direction to the single-yarn twist must be in the necessary proportion to not only produce an enduring or permanent "set" in the doubled yarn, but also produce the required characteristics as to strength, lustre, etc., of doubled yarn.

Although a balanced twist by the first definition may be used as a basis in some way or other, what doubled yarn is ordered to have such a balanced twist ? In the production of 2-fold voile yarns, for example, balanced twist seems out of the question, because the 2-fold twist is in the same direction as the single-yarn twist.

(2) This matter depends on a host of conditions, and it seems to me that each class of doubled yarn will have to be considered separately. Some doubled yarns (produced by one operation or by two operations) do not need strength as the primary requirement.

(3) I am inclined to say slow speed and as heavy a traveller as the yarn will stand.

Replies to the above Inquiry

Reply No. 1—We note in the *Journal of the Textile Institute*, Vol. XXV, January issue, page 7, an inquirer asks three questions relative to doubling.

The first question refers to any doubled or cabled yarns; balance being the designation of the state to which any of the aforementioned yarns can be finished. In the case of ply doubling, the twist in the singles is balanced by the twist in the doubling; or, in the case of a cabled yarn, by balancing the twist in the single and ply yarn, by the twist in the cabled yarn. Usually yarns are spun twist-way and are doubled weft-way; but, if for any particular purpose the yarns are to be doubled twist-way, then they must be spun weft-way in order to obtain a balanced yarn.

It may make it clearer to define balance in another way.

To balance the twist in the single yarn by twist in the doubled yarn, is to negative one twist with the other, so that when finished yarn is suspended, no tendency for the yarn to turn or spiral about its axis is seen.

We find that a balanced yarn is most often associated with knitting and crotcheting yarns, or any yarns in which the danger of "corkscrew" effect due to excessive twist would make it possible for the yarns to become entangled.

Referring to question 2, we do not consider that an answer should be given to this question in figures, as every single and doubled yarn must be judged on its merits, consideration being given to the properties of the fibre, the moisture content of the fibre and the method of production, etc. The answer to this question must be: "by experiment".

Points which will greatly affect strength are humidity, and whether the yarn is doubled dry or wet. In dry doubling it is quite possible to notice the tendency for splaying or shedding of fibre, which is not so apparent in wet doubling; and the correct twisting-in of these loose fibres must of necessity add to the strength of the finished yarn. Relative twists will affect the twist, and overtwisting is to be avoided.

From the foregoing remarks, the two features of strength and elasticity must not be confused, as strength is a term applied to a yarn in determining its point of breaking, whilst elasticity is the measurement of its elastic properties, and the insertion of twist may add or detract from this elasticity. Pages 93–97 of Section 3 of Wakefield's "Cotton Doubling and Twisting" describe certain efforts that have been made to determine the relative properties of elasticity and strength.

Question 3—Here again is a question which cannot be answered by a definite figure. The question of slow speed and heavy travellers as an aid to strength in doubled yarns can be associated with the older methods adopted by spinners and doublers, who spun and doubled yarn at slow speeds. It is generally accepted that the heavier the drag when spinning or doubling, the less the elasticity; and the lighter the tension, the greater the elasticity.

It is also agreed that heavy drag tends to maintain the fibres in a more parallel line, although the drag can be so great as to cause strains and irregularities in the strength of the finished yarn.

To summarise these few remarks, we consider that more can be gained by the experience obtained in doubling to the requirements of the specified yarn than by any knowledge acquired from either books or hearsay, as it is necessary to judge each yarn on its own particular merits.

Reply No. 2—Balance of twist in a doubled yarn may be defined as the number of turns per inch which may be inserted up to the point beyond which the yarn turns upon itself.

The maximum turns per inch in any given count of 2-fold yarn beyond which the yarn becomes weaker varies in that count—(*a*) with the type and quality of cotton—*e.g.* American, or Egyptian, or Sea Island, and (*b*) with the method of spinning—*e.g.* up or down.

To obtain the maximum strength on doubled yarns the employment of slow speed and heavy travellers is requisite. The traveller weight must be within limits, those limits varying with the count of yarn. The most important factor is the slow speed.

REVIEWS

Die Druckerei. Zeugdruck, Garndruck, Kunstseidendruck, Wolldruck, Seidendruck. By Professor Dr. E. Ristenpart. Published by M. Krayn, Berlin, W. (pp. 193, price 8.50 M.).

This is the sixth volume of a comprehensive work—"Chemische Technologie der Gespinstfasern", compiled by Dr. Ristenpart "for the benefit of bleachers, dyers, printers, and finishers", and is also recommended for use in technical schools and high schools.

Following a short article on the different styles of printing, and a very compressed historical survey of the art of textile printing, Chapter 4 is devoted to a description of the apparatus and machinery used in the printing industry. Some of the sectional diagrams are very clear and instructive, but the reproductions of photographs of actual printing machines are too confused to be of much value. The agers and driers described on pp. 34-41 are quite unlike those usually met with in this country, in that the cloth is made to travel in spirals instead of the better known system using horizontal rollers. In the chapter on thickeners an undue amount of space would appear to be devoted to the uses of Colloresin DK, a material which is expensive for practical printing, even though it may be a very interesting substance from the chemical point of view. Furthermore, it can in many cases be replaced by the much cheaper British-made Gum Tragasol. The recipes given on page 35 for the thickening of spray printing colours on account of their high concentration seem as if they would be somewhat difficult to work, and the suggested mixture of gum arabic with gum tragacanth is definitely stated on page 53 to be impracticable. The remainder of the book is devoted to a description of the methods for the application of the various classes of dyestuffs in direct printing, discharging, and reserving. No mention is made under the heading of direct colours of the satisfactory results that can be obtained by a subsequent fixation of certain dyes with the aid of Fixanol (I.C.I.) or Sapamine (S.C.I.), or by diazotising and developing, both in the case of direct prints, and when they are to be used as a ground colour for subsequent discharging.

Discharges on vat colours are very extensively dealt with. An interesting suggestion is the use of an alkaline solution of pyrogallol as a means of enhancing the activity of Leucotrope W for vat dyes that resist all normal methods of discharge. The classification of vats into five groups graded in order of dischargeability will also help considerably in the printing of vat dye discharges on vat-dyed grounds. The section dealing with the indigosols is somewhat out of date already. There is no mention made of the better colour yield to be obtained by the use of Dehapan O, and the alternative use of aluminium chlorate whereby the colours can be developed without steaming or an oxidation bath is not alluded to. For the diazotising of Fast Colour bases to be printed on to naphtholated cloth, the reader is referred to Volume III of the same series. In the volume under review only the treatment of a few of the more recent additions to the series of bases is described. And there is no mention of a method which is very useful in certain cases, the naphthol nitrite process. Otherwise the section on the use of azoic colours both for direct prints, discharges, and resists with Variamine Blue is very fully dealt with. The employment of Katanol O, in the aniline black section, is interesting, as a little known method of resisting with basic colours, as is also the use of a little rongalite for white resists, with the object of removing all traces of the greening which may arise between padding and printing, a difficulty which does not arise if sodium carbonyl ferrocyanide is used in place of the plain sodium ferrocyanide. Diphenyl Black, and the browns got from paraphenylene and meta amido-phenol, are dealt with at considerable length. The chapter on mordant colours also contains some very useful recipes. English text books do not as a rule devote much attention to the printing of cotton yarn, and the calico printer may find himself in considerable difficulties when he attempts to apply to this process the prescriptions to which he is accustomed. The author carefully points out in the yarn printing section the special bleaching methods and thickeners that are required for the achievement of successful results. A good description of yarn-printing machines is given with the other machinery on pp. 14-18. The machines used for the printing of wool, both in yarn and sliver, described on pp. 178-180, may also offer some useful suggestions for the production of novelty effects on cotton yarns. Section V deals with wool printing, and describes the production of direct prints with basic, acid, direct colours, indigosols, and mordant colours. Under the heading of discharge printing, a list of direct dyes is given which have the useful property of dyeing wool-viscose unions in level tones of good fastness to washing and perspiration. Furthermore, the discharges made on these colours show no tendency towards yellowing on exposure to light and air.

The book is well indexed, both as regards authors' names and subject matter. The index to the 61 printed patterns comes at the beginning of the book. This is a most aggravating feature. It would not have added appreciably to the cost of the book if two, instead of three, patterns had been given on a page, and this would have allowed ample room for a detailed description of the print.

Viewed as a whole, "Die Druckerei" can be considered as a very well-compiled collection of printing recipes. Very little has been left out, and there are a number of formulæ which are not commonly found in English text books on textile printing. That the dyestuffs recommended are mostly those made by the I.G. is only to be expected in a German book. But the English reader has always the Colour Index at his disposal in which to look up the English or American equivalent. The book is written in such a very simple style that its translation should offer no difficulties even to the printer with only a minimum of technical German at his command.

W. F. A. E.

Rayon and Synthetic Yarn Handbook. By E. W. K. Schwarz and H. R. Mauersberger. Published by the Rayon Publishing Co. (pp. 420, $3.00).

This book opens with a short history of the manufacture of rayon commencing with Hooke's notes in Micrographia of 1664, and proceeds with a concise but useful account of the four main processes for making rayon, reference being made to the Lilienfeld process and the Furness continuous spinning process. Useful notes on hollow filament yarns, artificial horse-hair, straw and ribbon, and transparent cellulose films, and statistics of production and consumption from 1911 onwards are given and it is shown that the rayon consumption for 1933 was 5·7% of the total of all textile fibres used and 6·87% of the cotton consumption, so that in the near future rayon is likely to become a serious competitor of cotton, consumption of rayon being already three times that of real silk. The physical and chemical properties of the various types of rayon are described and methods given for determining these and for distinguishing between them. Chapters are devoted to the weaving and knitting of rayon and to the dyeing, printing, and finishing of rayon in yarn and fabric. A useful list of trade marks complete the book, whilst a few level dyeing dyestuffs are mentioned; the question of level dyeing of variable rayon is not dealt with. The value of the book would be greatly increased by a more detailed description of the processes of manufacturing the various types of rayon. W. H.

The Principles of Economic Geography. By R. N. Rudmose Brown. Published by Sir Isaac Pitman & Sons Ltd., London, 1934, 3rd Edition (208 pp., price 6s.).

It is gradually becoming recognised that a knowledge of Economic Geography is necessary in commerce, and no commercial training is complete which does not include a study of Economic Geography. The value of such a study becomes increasingly clear as one reads Professor R. N. Rudmose Brown's lucid exposition of the principles of Economic Geography. Here is a reasoned study of the geographical factors which influence the production, transport, and marketing of the world's major commodities; knowledge essential to producer, salesman, buyer, shipping and railway agent alike; knowledge invaluable, too, for the politician and administrator. This is the justification, rather than the theme, of the book, which is a full review of the world's major resources and of labour, trade, and transport. The author is not only concerned with the present position but, where relevant, he traces development from the past and indicates future probabilities, e.g. he gives an account of the development and course of trade which enables him to show how geographical conditions have played their part in the past.

The author states in his preface that the book should be read with a good modern atlas and, on this ground, completely omits maps and diagrams from his book. This is an unfortunate omission which causes the text, in places, to become little more than an enumeration. This is most noticeable in the chapter on trade routes. One notices, too, the omission of any reference to artificial silk and the scanty treatment of aerial transport. In a text-book on the principles of Economic Geography one would have welcomed some indication of the geographical methods of treating statistics.

The book is characterised by the accuracy of its information, but two statements call for comment. On p. 82 the brewing industry at Burton is attributed to the "peculiar qualities" of the waters of the Trent, whereas the water used in the brewing is not drawn from the river but from wells sunk into the Trias, which yields a hard water eminently suitable for brewing. On p. 36 the chief problems in the extension of wheat cultivation are said to be to find varieties that will germinate with less rain and ripen at lower temperatures, but no mention is made of the more important problem, *viz.* to obtain varieties that will mature and ripen more quickly.

The volume must be commended for the wealth of information it contains at so reasonable a price and for its suitability for the general reader as well as for the student. C. L. M.

Conductimetric Analysis. By H. T. S. Britton, D.Sc., F.I.C. Chapman & Hall, Ltd., London (pp. xi + 178, 12s. 6d.).

The measurement of electrical conductivity in solutions has played a great part in the historical development of theoretical chemistry, since results obtained by it, led to the evolution by Arrhenius of the Theory of Ionic Dissociation. This concept has contributed very materially to the development of present-day theories of atomic structure and chemical combination. Although a technique of satisfactory accuracy in these measurements had been evolved by workers like Kohlrausch, conductivity measurements have not, until recent years, been widely adapted to the needs of analytical chemistry. It had long been recognised that they shared with potentiometric measurements important advantages in the titration of highly-coloured liquids where the visual indicators used in volumetric analysis are of little use, but the older method using a coil as oscillator, and a telephone as detector, had not seemed sufficiently attractive for general adoption. Now that silent oscillator circuits can be constructed cheaply from wireless components, and accurate A.C. galvanometers are available at a reasonable price, it is possible, as Dr. Britton shows, to construct an instrument which will measure variations in the conductivity of solutions so rapidly that a titration carried out by its aid takes little longer than a titration using a visual indicator. The chapters in which Dr. Britton deals with the experimental determination of conductivity might have been lengthened somewhat with advantage, since there is an obvious field for the adaptation of such methods in analytical control of industrial processes, and in adapting a procedure for routine testing, the smallest details are important. A number of references to the original sources helps to remedy this deficiency.

The same very mildly adverse criticism may be made of the two opening chapters in which basic ideas such as specific conductance, equivalent conductivity, ionic mobility, etc. are explained. These appear to be rather compressed and unemphatic and for this reason lack justification from two standpoints. To those who are at all acquainted with the physical chemistry of solutions the ideas will be so familiar that they should not need repetition. To those who know little physical chemistry the treatment given will be insufficient to drive home these fundamental ideas to an extent commensurate with their absolute importance. Many other writers of monographs seem to have the same difficulties with their opening chapters since they feel it is but logical that the elementary concepts in their subject should be mentioned, but they begrudge them space when there are newer and more fascinating matters to be dealt with ahead.

Several chapters are devoted to a consideration of the most important systems with which conductimetric analysis may have to deal, e.g. titrations of weak acids, strong acids, weak bases, and strong bases in all their possible combinations; titration of polybasic acids, very weak acids, mixed acids; replacement of acids and bases from their salts, the titration of abnormal and amphoteric electrolytes, and the very important class of titration in which some of the ions are removed by precipitation as insoluble salts. These chapters are generally well arranged and are selected to show the typical behaviour of the systems with which they deal. They show clearly the circumstances under which conductimetric titrations may be applied and the directions in which their accuracy is limited. They rightly stress the value of the method in the estimation of weak acids, such as boric, in which other methods are of little value.

A function of particular value shared by conductimetric and electrometric analysis is the demonstration of compound and complex formation in solution without the laborious processes of isolation of the new substances (often extremely unstable). This function is dealt with at some length and some idea is given of the complexity of these constitutional investigations.

In the last chapter, short notes are given gathered from a very wide range of sources, of the industrial applications of conductimetric methods, including water analysis; control of textile processing, paper-making, and tanning operations, dyestuff analysis, etc. These suggest further applications, and since the measurements are carried out by electrical means, there seems to be a prospect of their wider adaptation to the continuous automatic control of electrolyte concentration in solutions during the progress of industrial operations.

The book may be said, therefore, to give a generally competent survey of an important branch of physical chemistry. Dr. Britton's wide experience of the subject is a high qualification for the production of such a summary, and he has arranged and selected the large amount of material at his disposal in a clear and orderly fashion, so that it becomes readily available to all who require authoritative information. Like the rest of this series of monographs, the book is well printed and the standard of production is high. H. A. T.

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PROCEEDINGS

London Section

Meeting at Barrett Street Trade School, London, on Thursday, 8th February 1934; Mr. F. W. Walker, Chairman of the London Section of the Society of Dyers and Colourists, in the chair.

FASTNESS IN TEXTILES

The following is an abstract of the lecture delivered by Mr. C. M. Whittaker, B.Sc. (Courtaulds Limited), on this subject.

Mr. Whittaker first made it clear that the views expressed were definitely personal and provocative with the object of promoting discussion. All those who had any dealings with textiles were aware of the widely varying views regarding Fastness, and of the extraordinary difficulties which dyers frequently experienced in getting specifications of the degree of Fastness required. The enormous variety and uses of textiles made it inevitable that the standards of Fastness varied widely. He had advocated for years that the more particulars of Fastness which the dyers were given, the more efficient and cheaper service the dyers could give. More co-operation between the dyer and the manufacturer would be advantageous to both parties, and lead to economy in production.

The Fastness, said the lecturer, with which he wished to deal first was that of "Light Fastness" and some of the absurdities in connection with it—he would take the major absurdity "Guaranteed Fadeless." Surely "Fadeless" if taken literally, did not require any qualification such as "Absolutely". Those who were old enough to recall the first so-called "fadeless" fabrics placed on the market, would remember that the shades were limited to very heavy dull shades, which were admittedly of outstanding fastness to light, but not, of course, fadeless. As taste and design changed, a demand sprang up for brighter and pastel shades, which had also been included in the so-called "fadeless" ranges, with the result that "guaranteed fadeless" had become so degraded in meaning that all it meant to-day was that the fabric was dyed with vat colours. The distributors were compelled to limit their guarantee to so short a period as 12 months in many cases. Casement fabrics containing cotton, viscose, and acetate yarn were now on the market, but it was obvious to any technical man that a fabric containing these three fibres, could not be vat dyed in the majority of instances. It was agreed that the cotton and viscose might be vat dyed, but it was common agreement that the acetate dyestuffs, over a commercial range of shades, were not as fast to light as vat dyestuffs of casement fastness on cellulose. These fabrics were, however, included in "fadeless" ranges, and so the degradation of the term proceeded. There were a large number of casement and furnishing fabrics on the market, said Mr. Whittaker, in which the cotton was dyed with vat dyestuffs, and the viscose with direct cotton dyestuffs. He suspected that one of the reasons for this was that many yarn dyers fought shy of applying vat dyes to viscose.

It was obvious that the direct cotton colour-dyed yarn must inevitably fade before the vat-dyed yarn, and therefore give unsatisfactory service to the ultimate consumer.

The lecturer reminded the audience that the German Fastness Commission, the American Textile Chemists' Association, and the Society of Dyers and Colourists, had each spent much time on the establishment of standards of fastness to light. It was hoped to reach a common agreement eventually. Meanwhile, the English and German standards were patterns, on wool, of definite percentages, of definite dyestuffs, dyed under definitely specified conditions. Wool had been chosen because it was the fibre on which dyestuffs were the least sensitive to the moisture, sulphur fumes, etc., in the atmosphere. He emphasised that these standards were definite patterns and not dyestuffs. He had more than once protested against the abuse of these standards, in classifying the fastness to light of dyestuffs, which at present existed. Since no known dyestuff was equally fast to light in pale and heavy shades, it was, of course, obvious that no dyestuff could be of one standard of fastness in all depths of shade. Therefore, it was impossible to classify a dyestuff as equal to a particular standard, unless the actual percentage of the particular dyestuff which was equal to the standard named, was stated. The lecturer suggested that the percentage of the dyestuff which was equal to the standard named should be put on the pattern card itself.

Mr. Whittaker continued that it was his practice to expose all dyestuffs in a range of eight shades. This enabled a rapid and reasonable comparison of the relative fastness of dyestuffs to be made, by comparison of the relative fading of the eight depths of shade. Under these conditions, he had exposed eighty of the fastest to light direct cotton dyestuffs commercially available. From these he chose, what he considered to be, the eight fastest to light direct cotton dyestuffs in yellow, orange, brown, red, blue, green, and grey. Having done this he exposed these dyestuffs in four different depths on viscose and cotton, and obtained results which astonished him, and which had astonished others to whom he had shown the exposures. The first point these exposures confirmed was that a dyestuff on cotton was much less fast than a similar depth of dyestuff on viscose. This fact was, of course, known, but he could not recall the fact being stated on any light classification dealing with viscose and cotton.

The second point, continued the lecturer, which was astonishing, was that there was no direct cotton blue, grey, or green which was equal in fastness to light to the best direct cotton yellows, oranges, and reds. He suggested that the light classification tables which were at present published did not set forth this fact. If, on the other hand, his suggestion were adopted, this fact would emerge from the tables. This fact was very disturbing, because it meant that if one used the fastest to light direct cotton yellow, orange, brown, or red, there was not a single direct cotton blue, grey, or green of equal fastness to light which might be used with them for drabbing purposes in compound shades. Therefore, it was impossible, using these fastest dyestuffs, to produce a balanced fade in compound shades. It was suggested, said the lecturer, that the best direct cotton dyestuffs were almost equal in fastness to light to the vat dyestuffs. In his opinion, the direct cotton colours could not be compared for light fastness with the vat dyestuffs, and he exhibited samples in support of his contention.

The next "fastness" about which he wished to speak was the liability to tendering of casement curtains on exposure. For some years past, the distributors had had many complaints about curtains going tender after being hung; in some instances in a relatively short time. Many of these curtains had contained rayon as well as cotton, and the rayon—being initially weaker than the cotton—had given way first; although a detailed examination had shown that the cotton had deteriorated relatively as much as, and in some cases to a greater extent than the rayon. These complaints were very annoying and had raised an unjust prejudice against the use of rayon in casements. It was a very unjust prejudice, but it was taking a lot of uprooting. Experience showed that these tendering complaints occurred in all tones of yellow and orange, much less occasionally in red, but never in blue. Obviously, if the rayon were at fault and not the dyestuff, complaints should cover the whole range of casement shades, but they did not. Many workers had tackled this problem but no accepted explanation had yet been put forward. All workers were agreed that certain vat dyestuffs accelerated unduly the tendering of cellulosic fibres on exposure. Direct Cotton dyestuffs as a class did not cause this tendering. The prejudice against rayon in casements became so marked that with two of his colleagues, Mr. Delph and Mr. Hegan, joint work on this subject had been carried out for over three years. This work was summarised in a paper given before the Manchester Section of the Society of Dyers and Colourists, and showed clearly two points—

That certain vat dyestuffs unduly accelerated the tendering of cellulosic fibres on exposure.

That viscose rayon did not tender relatively at a greater rate than cotton when dyed with these dangerous vat dyestuffs; if dyed with the safe vat dyestuffs, rayon was perfectly suitable for use in casements.

A list of safe vat dyestuffs for use in casement dyeing had been circularised to the trade. Despite these precautionary steps, it was to be regretted that the dangerous vat dyestuffs were still being used for casements. He then referred to further work on the tendering question and said that it had always been puzzling to determine how complaints arose in so haphazard a way. Many sets of curtains would be made out of the same batch of dyed yarn, yet only one set of curtains out of this batch was the subject of a complaint. If one set tendered why did not all tender ? The explanation was, that local conditions under which the curtains were hung varied widely, and the question arose—"What are the variables ?" Their recent work had illustrated one important variable—the rate of the flow of air over or through the curtain. Pieces of the same fabric of viscose rayon were pinned on to a board and on to a frame. More air obviously passed through the fabric on the frame. Duplicate sets were exposed; one on a roof 42 ft. above ground level in a very exposed position and the other on a roof 24 ft. above ground level and much more sheltered. The exposure period was from the 10th to the 24th of May 1933, when 38 sun hours were recorded. The fluidity tests on these fabrics came out as follows—

Frame at 42 ft.	11·4	units increase
Board at 42 ft.	4·6	,,
Frame at 24 ft.	6·7	,,
Board at 24 ft.	3·8	,,

Mr. A. E. Delph had shown that this increase in degradation was due to the mechanical displacement of the threads by the increased flow of air with the result that more surface was available to be degraded by the light and atmosphere. It was, of course, obvious that there could be no shortage of oxygen, even on the board, but that it was the extra surface offered due to the mechanical displacement, and therefore the presentation of a greater surface to be chemically attacked. This was confirmed by the exposure of a range of viscose yarns from the finest to the coarsest denier. 75/18 to 500/54 denier yarns were exposed and it was found that the finest denier tendered the most rapidly under identical conditions of exposure. 75/18 increased 4·4 fluidity units in 20 sun-hours, and 11 fluidity units in 62·8 sun-hours, whereas the 500·54 denier only increased, in the same period, 0·7 and 6 fluidity units. The intermediate deniers fell between these two extremes with almost mathematical accuracy. These results, therefore, showed that the most suitable viscose rayon yarns for casement fabrics were the coarse denier yarns. It was also clear that the construction of a fabric played a very important part, and that a leno weave must tender more rapidly than a repp.

Fastness to "washing," said Mr. Whittaker, was not a fastness in textiles which was difficult to achieve. Provided the manufacturer was prepared to pay a reasonable price for the shades required, the dyer had at his disposal a large range of vat dyestuffs, azoic dyestuffs and sulphur dyestuffs, in order to give fast-to-washing articles. There was no technical difficulty in giving a complete range of shades which would withstand the severest washing, except in the brightest emerald, purple, and pink shades, which could only be obtained with basic dyestuffs. The misuse of the so-called oxygen washing powders had caused trouble from time to time. These powders were liable to have a severe stripping action on the sulphur dyestuff class, and, in his opinion, sulphur dyestuffs should be avoided in the highest class of washing articles. One source of complaint about looseness to washing was due to the use of material for trimming which was not fast to washing, and which was never intended to be fast to washing by its original manufacturer.

Fastness to "shrinking", continued the lecturer, was a problem which had received a great amount of attention with very satisfactory results. Shrinkage had led to bitter complaints from the distributors of casements, underclothing, shirting, and overalls. It had to be admitted that the craze for cheapness was responsible for some of these unsatisfactory fabrics, because the finisher had been compelled to deliver a definite length and width or to lose the business. To obtain this length and width, cloth had on occasion, to be deliberately stretched with the result that the first time it was wetted it recovered its natural length. On the other hand, with the best will in the world and taking every available precaution to prevent stretching, fabrics were inevitably stretched slightly in weaving, dyeing, and finishing. Regarding the shrinkage of casement curtains, it should be realised that when viscose rayon became damp or wet it lengthened to a maximum of 5%. He advised makers-up of curtains to cut slightly more than the length they required, and to hang the cut lengths in a dry room before they proceeded to make the hems.

Whilst not really a question of fastness, but of shade, he wished to make a few final remarks on the matter of shade in corsets. It was his unfortunate position to dye yarns for the corset cloth manufacturer, for the corset webbing manufacturer, and for the corset trimming manufacturer. The fabric, the webbing, and the trimming must be exactly alike in tone; and each of these three branches tyrannise over the dyer in rejecting deliveries, etc. In the first place he ventured to suggest that the ultimate wearer of the corset was relatively indifferent to the exact tone, and this insistence on the exact tone, was a fiction of someone further back in the trade. It is to be noted that this insistence increased in inverse ratio to the rate at which the particular line of goods was selling. The fact of the matter was that it was only when England went off the Gold Standard, and put on tariffs that some people entered the corset trade. Now one fact emerged in an examination of a large number of foreign-made corset cloths, it was found that many contained pink shades dyed with basic colours, and, therefore, were extremely fugitive. He attributed this to the fact that in the days when real silk was used in corsets, the pink would originally be dyed with Eosine or Rhodamine. No English dyer could imitate these shades without the use of the same basic colours. Immediately the complaint of fading was received, the English dyer was condemned as incompetent compared with his Continental confrère. He challenged the fastness of the Continental fabric and eventually received sufficient to make comparative exposures. Three days in February were enough to show that the Continental fabric was more fugitive to light than his own dyeing.

After a good discussion, Mr. John Howard proposed, and Mr. Blair seconded that a vote of thanks be given to the lecturer. This was heartily accorded and briefly responded to by Mr. Whittaker.

London Section

Meeting at the Section Rooms at 104 Newgate Street, London, on Wednesday, 21st February 1934; Mr. G. Canham in the chair.

THE HOSIERY TRADE

Mr. J. Chamberlain (Fellow), of the Leicester College of Technology, delivered this lecture of which the following is an abstract.

In the first place the hosiery trade obviously dealt with the manufacture of hose, and in America, Australia, and most other countries the hosiery trade meant the manufacture of hose, half-hose, and socks. In Great Britain, however, anything made on a knitted basis was called hosiery. There were various forms of hosiery—ladies' hose, men's hose, and half-hose; the term "socks" was only applied to children's wear. These different hosiery types were made on different principles, on different gauges, and in different ways. The highest priced product was the ladies' full-fashioned pure silk hose. It was made on a single unit machine and only required seaming before it was made into hose. It was possible to fashion the leg, join the heels, and seam down the leg, and so get the whole thing made in the one piece. This was not the general way, but a method that had been devised recently. The more general method was for such hose to be made in two parts, the leg on one machine and afterwards the foot.

Seamless hose was next described. This type was made on one machine in one width and operation; it only required joining at the toes. Mr. Chamberlain then turned to underwear and lingerie, and said that in this case there were two ways of making garments. Either fabric was used and the garments cut out with an electric cutter and joined up, or the goods were fashioned direct on the machine. The latter method was the more expensive, but it could be carried out both with underwear and outerwear. All sorts of articles containing rubber in different ways were knitted for brassiéres, corsets, etc. One object was to get the underwear as accurately fitting as the outerwear. It had the advantage that it could be used in certain parts of the garment—inserted in the ordinary knitting so that there was no question of bulk in seaming. There were great differences in the stitches used, as for example, plain, interlock, locknit, atlas, or milanese, but there was nothing stable about knitted fabrics, and producers all the while were trying to find something different.

A series of fabric samples and slides were then shown and in the course of his explanatory remarks the lecturer said that the hosiery trade claimed to have had something to do with dress reform. He hoped that more use would be made of knitted goods. He illustrated how it was possible to speed up manufacture on certain machines. Referring to the locknit stitch, he said that although the rayon firms had really popularised this stitch, it was made something like 100 years before they came into existence.

The lecturer next referred to warp knitting which had been persevered with to a much greater extent in Germany. Until the war, we almost neglected it. Originally warp knitting machines were made in England, but the Germans foresaw the possibilities and made various improvements, and now exported large quantities of fabrics of all sorts. Since the war we had taken it up and, after duties had been imposed on the materials, we had made still further progress. The lecturer concluded his remarks by describing the various methods of seaming, all of which were shown by lantern slides.

Mr. W. H. Matthews (Board of Trade) proposed a vote of thanks to Mr. Chamberlain, and it was carried with acclamation, the lecturer briefly responding.

NOTES AND NOTICES

Appointment for Institute Scholarship Holder

Members interested in the Scholarship Scheme planned and administered by a Committee of the Institute, will note with satisfaction that the Second Scholarship holder, Mr. William Graham, has, immediately after his scholarship period closed, secured a most satisfactory engagement. He has been appointed to the Administrative Staff of Messrs. Rylands & Sons Ltd., in connection with the various and extensive productive works of this well-known firm. Gratifying as this appointment is, it becomes doubly so when it can be recorded as the outcome of efforts of members of the Committee, and also for the reason that the appointment was competitive. The engagement itself is almost entirely due to Mr. A. Pollitt, a Director of Messrs. Rylands & Sons Ltd., for many years President of the British Association of Managers of Textile Works, and for an equal period a member of the Textile Institute. Mr. S. Watson, Vice-Chairman of the Council, drew the attention of Mr. Pollitt to Mr. Graham, and the Scholarship Committee's thanks are due to him for this service. The post is one of definite promise and, considered in conjunction with that secured by the first Scholarship holder, Mr. A. Ratcliffe, should give the founders of the Scheme, the Cotton Trade Reconstruction Board, every satisfaction. It is anticipated that an announcement will be made early in 1935 as to the award of the third scholarship.

REVIEWS

Textiles and the Microscope. By. E. R. Schwartz. Published by McGraw-Hill, London, 1934 (329 pp., 307 figures, price 24/-).

The author offers this book as an introduction to textile microscopy intended to stimulate interest and to encourage research; for, although he believes an exhaustive work is needed, he considers that there is not sufficient material for so complete a work. A readable book has resulted, which contains some new matter, and, of more importance, much information that had been widely scattered is now collected in one cover. Certain deliberate omissions have been made in the text, which the bibliography is intended to make good. This contains the titles and references to nearly 300 communications in books and journals, which will be of value to all serious workers, but it is regrettable that the author relegated so much matter to bare titular references and did not weave it into the body of the text.

The best sections are those devoted to yarn and fabric analysis, which are illustrated by many good photomicrographs, though the good general impression is weakened by the inclusion of some of inferior quality, in particular Fig. 251 is very poor. The study of yarns and fabrics with the microscope is extended in a very interesting chapter to include stereoscopic photomicrography.

It is surprising that staining and swelling methods and dark ground illumination are passed over with the briefest descriptions although these are important elements of technique, as important as polarised light methods, to a description of which 20 pages are devoted. The subject matter of the last-named section is undoubtedly difficult to present clearly, especially in a small space. Probably a happier treatment would have been achieved if either more or less knowledge had been assumed to be possessed by the reader. The description given on pp. 226-227 of the measurement of the refractive indices of fibres is misleading and should be thoroughly revised in subsequent editions.

The book is copiously illustrated with about 300 photomicrographs and diagrams, which materially add to the value and attractiveness of the whole. Diagrams illustrating the principles and internal construction of apparatus are generally of more value than half-tone photographs of their external appearance. For this reason it is regrettable that so many of the illustrations are half-tone photographs culled from instrument-makers' catalogues. There is an adequate subject index. R.M.P.

The Dermatergoses or Occupational Affections of the Skin, Giving Descriptions of the Trade Processes, the Responsible Agents and Their Action. By R. Prosser White, M.D. (Ed.), M.R.C.S. (Lond.). Published by H. K. Lewis & Co. Ltd., London, 1934. Fourth Edition. (Pp. xvi and 716 demy 8vo, price 35/- net.)

The first edition of this work was published in 1915 and filled a gap in the literature of the subject for it has since then been translated into more than one European language and there have been several editions in America, so well was it received over there. Dr. White was also invited by the Labour Bureau of the United States Government to deliver a series of lectures in America on the occupational diseases of the skin, but at the then age of 75 he had to decline the honourable invitation. The subject of the book has been almost a lifetime's study by the author. Enlargement of each edition has been necessary because of the constantly increasing number of harmful materials used in industry; of the close watch paid by Governments of all nations to dangerous trades, and of the increasing number of officials and medical men writing about them.

This monumental fourth edition is easily the greatest compilation of facts and references that has ever been published on the subject and it will long remain its standard text book. The present writer has seen many medical books in his time, but no other like this in fulness and completeness of presentation. Over 2,400 authorities and their writings are referred to and the general index of its contents occupies actually 269 pages in double columns of small print. This index is described as synoptical in form, the information in it being so given that reference to the text may often be saved.

The publishers' note to this edition says, "It will readily be acknowledged that this volume is a monument to the author's painstaking thoroughness and patient, unflagging industry in collecting records from the widest range of periodical literature, while many of the facts quoted, being from private 'communications', testify to the world-wide reputation his devotion to the subject had secured". Its quality is equal to its quantity and of the greatest value to all who come in contact with diseases of the skin which arise out of and in the course of employment, or which are, in terms of the Workmen's Compensation Act, one form or another of "dermatitis produced by dust or liquids".

As the title says, it deals only with skin affections called dermatergoses, a somewhat new word in medical science, which means skin diseases arising from work.

The diseases which will chiefly interest members of the Technical Institute are those which arise in their own industries. The most important of these is cancer of the skin which is met with in mule spinners chiefly of Lancashire and Cheshire. Attention was first drawn to this disease in 1905 by the late Dr. S. R. Wilson who noticed several men in the Manchester Royal Infirmary with cancer of the scrotum, which used to occur 100 years ago so frequently in chimney sweeps that it was known as "chimney-sweeps' cancer". Wilson found, however, that these men were mule spinners, and further investigation revealed the fact that the disease was so much more prevalent in these cotton operatives than in any other worker in a cotton mill or any other trade, or in the population generally, that an inquiry was ordered in 1925 by a Departmental Committee of the Home Office into its prevalence, causation, and measures likely to prevent its occurrence. This Committee reported that the disease had become more common since the spindles of the mules were lubricated with mineral oil instead of the animal and vegetable oils of earlier spinning days, and that mineral oil was the real cause of it.

This form of cancer, or epitheliomatosis ulceration of the skin, as it is called in the Workmen's Compensation Act, may affect the skin of any part of the body and it is the cause of much time lost and expense to employers in compensating sufferers from it. It does not affect the operatives in the mule room of the woollen industry. A contributing cause to affecting the worker in the mule room more than in any other spinning trade is the unusually high temperature at which these rooms are kept.

The different mineral oils which are used in cotton mills have been studied carefully by the Manchester Cancer Research Committee and simple means to select the least harmful ones have been devised. Similar cancerous growths affect workers in the Shale Oil Industry of Scotland, but fortunately the Manchester scientists have discovered successful measures for protecting the workmen in this industry.

Many of the chemicals used in the bleaching and finishing industries are liable to affect the skin, and in dyeing and calico printing the aniline dyes are a frequent source of disablement; indeed, so many likely materials used in the textile trades are irritating to the skin that with few exceptions the actual causative agent need not be specified in certificates of disablement any nearer than it is a "dust or liquid".

The plates in the book are extraordinarily good representations of the affections they illustrate. On the whole it is an invaluable work of reference which ought to find a place in the libraries of the scientists attached to the numerous industries in which skin troubles are likely to arise. E. M. B.

GENERAL ITEM

LANCASHIRE EDUCATION COMMITTEE

Prizes for Woven Fabrics

Awards of prizes in connection with the annual competition of the Lancashire Education Committee, for specimens of woven fabrics submitted by students resident in the administrative county, are announced as follow—

First prize (£5)—Norman Pearson, Chorley Technical School.

Second prize (£4)—Albert Bolas, Chorley.

Third prize (two awards of £3)—Robert E. Riley, Colne; Joseph Radcliffe, Nelson.

The Adjudicating Committee of the Textile Institute recommended the foregoing awards, which were fully approved, together with the following report—

"The Adjudicating Committee having carefully examined the seventy-six specimens of woven fabrics, together with the same number of costing specifications, have pleasure in reporting that the modified scheme of competition promises to become a valuable adjunct to the City and Guilds examinations. The Committee consider that, as examples of textile design and fabric structure, the quality of the work submitted is highly commendable. From the point of view of commercial value and fashion, the fabrics possess much merit, but there is room for improvement in taste and colour harmony.

The Committee agree with the evident desire to make correct costing a prominent feature of the competition and have assessed this part of the competitors' efforts as representing 25% of the total marks. As costing of the cloths is demanded as part of the Competition Scheme, the Committee agreed that it is of the utmost importance that the work should be accurately carried out and that a really satisfactory basis of production costs should be associated with the estimates submitted. It is desirable that students should be familiar with the manner in which overhead charges may vary in relation to fabric structure and ornamentation, type of loom required, cost of gaiting, and the amount of cloth to be produced from a given design.

The Committee realises that knowledge of cost estimation may not be essential in the case of all designers and colourists, but participants in this competition may often be expected to combine novelty of effect with economical production. Ability to estimate cost on sound lines is, therefore, of great value. It is regretted that many of the calculations submitted have been found to contain serious and careless errors.

The Committee considers the entry for the competition—19 competitors—as most satisfactory under the altered conditions. Selection for the awards was only arrived at after most careful consideration. For the third position in awards, it is hoped that an extra third prize will be granted as Nos. 6 and 4 are of equal merit.

For the Committee's convenience in checking the accuracy of the calculations, it is suggested that in future the costings be submitted on detached sheets, each distinctly marked with a number corresponding to the number of the specimen costed."

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PROCEEDINGS

Yorkshire Section

Meeting at the Midland Hotel, Bradford, on Thursday, 22nd February 1934;
Mr. T. H. Robinson presiding.

(i) FAULTS IN WOOL TOPS; (ii) TEXTILE EDUCATION IN LONDON; (iii) WARPING WORSTED WARPS TO PATTERN

This meeting was an innovation in that three short papers were presented each by an Associate of the Institute. An interesting discussion followed each paper and at the close the contributors were warmly thanked for their services. The following are abstracts of the papers.

Faults in Wool Tops. *By* H Haigh.

Topmaking might be looked upon as the establishment of a basis from which all following operations, drawing, spinning, weaving, etc. proceeded. Thus it was very necessary that tops should be as free from faults as possible. The faults to which tops were liable might be divided into two classes, namely (1) Noticeable Defects, and (2) Hidden Defects. These classes would be dealt with in this order.

After giving a brief sketch of the process of making a top, Mr. Haigh said that the topmaker had only one ball or at the most two on which to judge the result of his blending. There might be a fault with the colour. If so then it would be seen at once. The colour was generally important and tops, particularly fine tops, should be as white as possible. If it were a poor colour the scourers were not getting all the dirt out of the wool; or the fault might be with the wool itself; too much skin wool in a blend or all skin wool would tend to create a dirty coloured top. With skin wool in the blend more care was required in the scouring. But in attempting to get a good white, care must be taken not to adversely affect the material.

Looseness was a very noticeable fault, continued the speaker, and made itself evident as soon as one made a draw from the sliver. The fibres appeared to have no cohesion; each appeared entirely independent of its neighbour. That characteristic so important for spinning, namely "clinginess" seemed to be lacking. This might be due to newness if the top were hot off the combs. The wool in the blend might cause this fault; any low quality wools were apt to cause looseness in the top. A too-dry top might be rather loose, but this, however, would be remedied by the addition of more moisture and oil. Where the wool was at fault either more greasy wool was introduced into the blend or the top would be sold with this fault. Sometimes a top loose in the fibre, due to the type of wool used, would have additional oil put on to cover up this lack of adhesion. Looseness might also be caused by over-scouring in the attempt to get a good white colour. This was most likely to occur with medium cross-bred tops. Prevention rested with the scouring operatives.

Handle, said Mr. Haigh, was a very important point especially with fine tops. If this were wrong, it would have an effect throughout the processes and would be most evident in the finished fabric. The handle of a top might be spoilt by over-scouring. Too much slipe would always tend to harshen the handle of a top, therefore the maker must allow for this in the blend. Monte Video wools also were apt to give a hard handling effect in the top. If, of course, all M.V. wool was used in the top and sold as such, this inferior handle would not be a fault as it was part and parcel of the particular type of top.

The damage caused by vegetable matter was next referred to. Care in sorting would help to eliminate this, pieces containing "shives" should be thrown out; a careful watch should be kept for straws, etc., and most particularly all pieces of string should be picked out. Pieces of string caused terrific havoc if they passed through the processes, as also did pieces of bagging, hemp, etc.

Low hairs in Merino tops, continued the speaker, were a dangerous fault and often their presence could have been avoided. Greater care and watchfulness would prevent this fault. The use of badly bred wool would also cause this fault as poor breeding generally means occasional low fibres in the wool. Only the person responsible for the choice of wool could prevent this.

Hidden faults formed the second part of the address, and Mr. Haigh pointed out that such faults as these were generally only discovered when the tops were being used. Hence there was no chance of rectifying them unless the work was done over again. Re-gilling would rectify some of the faults noted.

Bad combing, said Mr. Haigh, included faults made during finishing. These faults might take the form of thick and thin places at regular intervals throughout the top and very often were only detected by the drawing operatives. Good operatives quickly noted any unevenness and if too bad the tops were returned to the comber and re-gilled. The cause was a too hard draft on the gill boxes, and this was most liable with short fibred tops. This fault was occasionally caused by neglect on the part of the operative. When several ends were running up to the finisher gill-box, and one broke down, the operative might not see it at once and a few yards would run through with one slubbing short. When the end was put in again, unless care was taken, a portion of the slubbing would overlap, this then caused the thin-and-thick place.

Worn leathers on rollers, he continued, might cause a variety of faults, such as unevenness of sliver due to uneven delivery of the rollers and also the rubbing of the sliver into a pith-like state. Such a fault as this would quickly be seen and recurrence avoided. Another fault which might be serious was the presence of minute dark hairs in the top. Because of this the "creams trade" only used yarns made from 70's quality. It had been found that 70's tops were much less liable to this defect than 64's. If, however, the yarns were for dyeing this fault was not as serious.

Mr. Haigh concluded by reference to lack of strength in tops which he attributed to the use of unsound wools and to bad blending which, though not easily discovered, was of the utmost importance. It should be avoided by using every care in the making of the pile where even layers of wool should be made, and by pulling the wool thus piled evenly from the face. He urged that practically all the faults enumerated could be eliminated by the exercise of the proper precautions.

Textile Education in London. *By* H. S. Newsome.

Textile classes were first started in London at the commencement of the present century. The honour of being the pioneer of textile courses in London belonged to Mr. A. E. Garrett. About 1896 he was asked to give a series of Economic lectures on Commodities, dealing with Iron and Steel, Coal, Textiles, and other Basic Industries. Experience showed that the demand for a closer and more detailed study of textiles was greater at that time than for any other commodity. Thus shortly after their commencement these classes became wholly textile. The syllabus covered the elementary sections of textiles and was of a similar nature to the course in General Textiles at the City of London College at the present time. About 1910 an attempt was made to start a series of Textile courses at the Regent Street Polytechnic. These classes were allowed to lapse, because about this time the Polytechnic was re-built and altered, and the classes were abandoned, rather than seek accommodation elsewhere. In the autumn of 1911, Textile Courses were launched at the City of London College. Mr. A. E. Garrett was the principal lecturer and Mr. Hooper also gave a series of lectures on Silk during the first session. At the commencement of the second year, Mr. Garrett took over the whole of the courses and modelled them into a General Course on Textiles. The Course he had been giving at the Aldersgate Street Y.M.C.A. was now transferred to the City of London College, and continued in that form until the year of 1927/1928, when Mr. Garrett retired.

Mr. Newsome next referred to the part played by the London County Council in the development of Textile Education in London. In 1917 an official in the Education offices of the L.C.C. suggested the formation of part-time day classes in "Distributive Textiles", primarily for the employées of the large retail stores. A committee was formed to assist in the development of these courses. Students were released from employment under conditions similar to those now applying in the North for part-time students. These classes were held at the Central Schools of Arts and Crafts in Southampton Row. There was, apparently no anticipation of the continuance of these classes and they only had a life of two years. Then the Assistance Committee reported to the General Council the desirability of their transference to more convenient centres. Accordingly, in the early part of 1919 the Council approved of the formation of Textile courses at the following four centres: (1) Camberwell, (2) Hammersmith, (3) Barrett Street Trade Schools, (4) Rooms in Tottenham Court Road, which were hired specially for this purpose. These classes were a failure from their commencement. At one centre no students attended, and at the others the numbers who did attend were so few as to make the continuance of these classes impossible. Accordingly in the latter part of 1919 all four centres were closed. Running concurrently with these classes practically from their commencement in 1917, were classes held at Barrett Street Trade School for girls employed in the workrooms of the West End houses. They incorporated a certain amount of elementary textiles along with the main courses in Dressmaking, Designing, and Millinery. These classes were organised and run by a special committee, composed of the heads of the West End stores, on behalf of the Education Committee of the London County Council. In 1922 this Advisory Committee suggested the formation of evening classes in "Distributive Textiles" for the selling staffs of the London Retail Houses. The former Assistance Committee which, on the failure of the previous classes, had become defunct, took over the suggestion on the distributive side only. Their name was changed to the Consultative Committee for Classes for Distributors. Barrett Street Trade Schools were suggested as the best centre.

These new classes were to embrace all sections of the Textile industry, together with the allied trades such as Furs, Leather, Boots and Shoes. These classes all took the form of short courses of five lectures in each section. Every lecture and series of lectures were to be complete in themselves, yet they were so arranged so as to form a constructive and continuous course on any particular section, should the students so desire to take them. The lecturers were mostly appointed in collaboration with the London Section of the Textile Institute. The courses were continuing in their present form and it was not anticipated there would be any radical alteration in the method adopted for some years to come.

About 1922, continued the speaker, the Principal of the Day Continuation School at Westminster, proposed the running of part-time classes in Textiles. These courses were to train young boys leaving school for either salesmen or buyers in the West End Houses. The scheme was approved both by the L.C.C. Education

Committee and by the business houses concerned, and the School of Retail Distribution came into being. Success in the establishing of the day classes led to the formation of evening classes and the school had throughout enjoyed a fair measure of success.

The City of London College and the School of Retail Distribution, said Mr. Newsome, were the two main centres at present for the teaching of textiles in London, whilst the latter was the only school in which day-classes in textiles were held. During the past two or three years classes in Textile Salesmanship had been held at Schools in Wimbledon, East Ham, and Stepney, the latter being run at the request of the Co-operative Wholesale Society who had their London headquarters and workrooms in Leman Street, near to the Stepney Evening Institute. The North-Western Polytechnic and the Borough Polytechnic also ran classes in Textile Advertising and Salesmanship, with the approval of the L.C.C. Education Committee on similar lines to the School of Retail Distribution Evening Classes. Similar classes had also been promoted at Peckham, Norwood, and Streatham, but these had been a comparative failure.

The lecturer next referred to the question of Examinations. The London Chamber of Commerce had held examinations in sections similar to those now in vogue at the City of London College. The School of Retail Distribution, however, had never had an external examination, and in 1931 the City and Guilds of London Institute was approached as to the possibilities of awarding Certificates in Retail Distribution. A Committee was formed and in the 1932/33 session an examination in "The Principles of Retail Distribution" was held. This examination, although Wholesale distributors were not barred from entering, was primarily for Retail distributors.

Realising this, the authorities of the City of London College, in collaboration with the London Chamber of Commerce approached the City and Guilds of London Institute for the institution of an examination in "The Principles of Wholesale Distribution", on similar lines to that on Retail distribution. The scheme was still under consideration by the sub-committee appointed by the various bodies.

In conclusion, Mr. Newsome considered the question "What exactly is the purpose of Textile Classes in London" ? Originally the classes were intended solely as a means of giving salesmen a slight knowledge of the fabrics they constantly handled. To-day, this intention had been considerably amplified and enlarged. Students were trained not only for Salesmanship but also for the Buying side of the trade. It had been realised that if future buyers had a thorough knowledge of raw materials; of the processing of those raw materials to the finished fabric and of the requirements of each individual set of processes, a closer co-operation and collaboration would be possible between Buyers and Manufacturers. Manufacturers had suffered from the type of Buyer who knew what he wanted but could not tell them what it was. Much time and money had been lost by a lack of understanding amongst Buyers as to exactly what could be expected from a particular type fabric. Many times a fabric had been put to a use for which it was totally unsuitable. It was, then, to obviate much of such misunderstanding that the Textile classes were being run to-day. Their progress might be slow but in the end it was hoped that the ideals of those who instigated these classes would be realised.

Warping Worsted Warps to Pattern. *By* W. L. Plunkett.

Warping, said the speaker, might be defined as the transition from length to area, as it was the first process in cloth manufacture where length and width had to be considered.

Warping might be considered, either as a final operation of the spinner or a preparatory process of the manufacturer. Speaking as a spinner, he thought that mutual satisfaction would be obtained if manufacturers were to take over all warping operations, taking delivery of yarn on cheese or warping bobbins.

He thought that the manufacturer might, in view of the importance to him of this preparatory process, take more care than the spinner to whom it is a finishing process. If manufacturers were to do their own warping, dog-legged flanges, loose-collars, and gudgeon pins would be things of the past, whereas at the present they were, with a few exceptions, a source of trouble and delay to the spinner.

He thought the manufacturers present would not agree with him and that many would, no doubt, think this would be a retrograde step, however the point was one which could form the basis of an interesting debate.

Warping to pattern, he continued, might be divided into three groups—using right and left twist yarns; using all wool yarns with union or rayon and wool twists; and using all-wool yarns and coloured unions with a large number of turns, solid cotton, or hard twist cord yarns, either singly or in combination.

The first two groups presented no real difficulties provided reasonable care was taken in tinting and creeling. Group 3 was the most important and presented the greatest problems owing to the different characteristics of the yarns being used and the necessity which often arose for allowing greater lengths of some of the cotton stripes to allow for take-up in the weaving and skrinkage in the finishing. Opinion was divided regarding this group and the three methods employed might be classed as—Dressing, Rollers, and Waving Motion. Each had its supporters who contend their method is the best for the production of perfect pieces and certainly each had its own particular merits.

Where expense had not to be considered, continued Mr. Plunkett, and the variation in length of the stripes was not too great, dressing produced the best weaving warps from the point of view of lost or broken ends and saved much time in the subsequent weaving. His only quarrel with dressing was in regard to the tensioning of the ball warps on entering the dressing frame. How often had one heard the remark "I am about two yards out in these two cut marks, but I will level them up before the next ones are reached". Tension would then be added or taken off in the hope of producing this result. Slight variations in the measuring rollers of two warping mills could cause a variation in length such as this. The tension applied in dressing probably not being the cause at all, an alteration of this tension might only make matters worse.

Some manufacturers swear by rollers, said the speaker, and this method consisted of placing the striping ends on a roller which was then placed at the back of the loom above the warp beam and the ends allowed to be drawn into the cloth with only a small tension on the roller, so that the weave might take in the extra length required. The happy medium between "cracked ends" and "looping" would appear to be almost unobtainable as both faults often appeared in the same piece due to uneven take-up in weaving.

Mr. Plunkett next described the actual insertion of stripes on the warping mill itself, which he claimed was the quickest and cheapest method of all, and certainly, from the number of problems and difficulties presented, the most interesing. The unavoidable problems were largely caused by the difference in counts and twist of the component yarns in a patterned warp. Excessive twist causing snarling might be overcome by steaming the cheeses in an oven from 3 to 5 minutes without damaging the paper tube. This applied more to some of the fancy union twists such as 2/36 with 30–40 turns per inch and to the cord yarn type of stripings. The difficulty of uneven over-running of the cheeses in the creel when starting or stopping the swift during running-on could only be overcome by seeing that the take-up of the friction drive was as smooth as possible and that the swift was running easily so that it did not lose its speed too rapidly after the stop rod was used. A centrifugal clutch or fluid flywheel type of drive to the swift would be of great help in these cases where of necessity the size of the cheeses in the creel varies and varying degrees of over-run cause felters.

Where the extra length of striping required only amounted to 1, 2, or even 3 yards per cut longer than the ground, he continued, this might be obtained without the use of the waving-motion by tensioning the ground ends by running them under the leasing bow before entering the leasing sley whilst the striping ends are allowed to run straight through. This method had proved very satisfactory in actual practice.

The uncertain and possible inaccuracy of other methods led to the invention of the Waving Motion, said Mr. Plunkett, by means of which five variations in length might be obtained and repeated with an accuracy before unobtainable. The ends requiring the greater length were passed through a small vertical inverted comb placed between the section sley and the measuring rollers, the ground ends passing above. This comb was given an oscillating movement in a horizontal plane by cranks working from a wheel on the end of the measuring roller. This wheel had five holes set eccentrically from its centre giving five lengths of pick or traverse to the comb. This enabled increased lengths of stripings from 2–6 yards per cut to be obtained depending upon the hole in which the first crank was set. In weaves where cracked or broken ends were troublesome in the finished pieces, this motion was undoubtedly helpful and, once the correct ratio has been found, reduced this trouble to a minimum. Other modifications which could be effected so that the full benefits of the Waver were obtained, were described by the speaker, who also briefly discussed the costs of warping.

London Section

Meeting at the Section Rooms, 104 *Newgate Street, London, on Wednesday,* 28*th February* 1934; *Mr. J. Howard in the chair.*

STANDARD LANCASHIRE FABRICS

At this meeting Mr. L. J. Mills (Fellow) was the speaker, and he illustrated his remarks with a number of very interesting samples. Several questions were asked at the conclusion of Mr. Mills' address to which he replied. A vote of thanks terminated an instructive meeting. Mr. Mills spoke mainly from notes, but during the course of his address distributed duplicated copies of particulars of two classes of fabrics which are reproduced hereunder.

Longcloth

The term Longcloth has been in use for hundreds of years. For example, in the Rates and Customs House Duties 1545, "one long cloth makyth one shorte cloth and VII yarde". In those days, it is probable that the term was applied to any cotton cloth or calico woven in long length for domestic purposes. Another possible reason for the use of the term longcloth is its utility, such as long white dresses or robes for infants, long night gowns, and so on. Another, but less likely, reason for the use of the term longcloth is by analogy with broadcloth and thus to differentiate therefrom.

Longcloth was originally a comparatively fine fabric, consisting of 60's to 80s' warp and 40's to 60's weft, good quality or super yarns, and 96 ends and 90 picks per inch. In current practice, longcloth is a medium-weight shirting style of bleached cotton cloth, fairly close in texture, usually plain weave, but in some cases the weave is the ordinary 2-and-2 twill. It is made in several widths and in numerous qualities, due to competition, manufacturers' and customers' personal preferences, etc: From 28 to 40 in. wide and from 28's to 36's warp and from 18's to 38's weft probably include the majority of longcloths made to-day.

Longcloth is bleached, cockle finished, and with very little filling added, say, 3 to 4% after the actual bleaching, mangling, drying, and calendering. It is dull or unglazed in finish and the cloth should be easy to sew. Nearly all longcloths are heavier than cambrics and madapollams, and are usually made from American cotton yarns, but the very best qualities are made from somewhat better yarns spun from the lower qualities of Egyptian cotton. Typical examples are as follows—

(*a*) Comparatively coarse quality: 57 ends and 42 picks per inch, 28's warp and 18's weft.

(*b*) An ordinary quality: 60 ends and 60 picks per inch, 30's warp and 30's weft, 34 to 36 in. wide, 36 yards long as received by the distributor.

(*c*) A still better quality: 72 ends and 72 picks per inch, 36's warp and 38's weft, 28 to 36 in. wide.

The fabric should be fairly evenly woven, but it is not usually free from slight unevenness in the picks when the weft is replenished. Longcloth should have good selvedges about 1/10th in. wide and be free from any wavy or saw-like effect at the extreme edges. In the average qualities of longcloth, common faults are (*a*) irregularity in the weft due to insufficient tension on the weft during weaving allowing small loops to form ¼ to ½ in. long; (*b*) broken warp ends during weaving not promptly repaired at the loom; (*c*) faulty restarting place after the weaver has placed a full shuttle of weft in the loom, resulting in a few picks very irregularly spaced—and may appear either as a thick or thin place across the cloth.

Cotton Sheets

Cotton bed sheets are made in the plain weave and 2-and-2 twill, and are usually bleached, but in some cases are sold in the unbleached, natural, or grey state. Common sizes of sheets are as follows—

in.		in.		
58	×	78		
60 to 63	×	100		
70 to 72	×	108	termed	2 × 3 yd.
80	×	100		
80 to 81	×	108	,,	2¼ × 3 yd.
90	×	108	,,	2½ × 3 yd.

The superior qualities of cotton sheets are made from virgin cotton throughout, 2-fold or single American warp yarn and single American weft yarn. Other cottons are also used for spinning into yarns suitable for sheets, depending, in some cases, on the country in which the cotton is spun into yarn. Cotton sheets of superior qualities are usually made from 22's to 26's warp and similar counts of weft. Such sheets are about balanced in ends and picks per inch and in counts of yarns. Examples are: (1) 78 ends per inch of 24's warp and 74 picks per inch of 22's weft, (2) 72 ends per inch of 24's warp and 70 picks per inch of 27's weft. Sheets 2 × 3 yd. made from such particulars will weigh 1¾ to 2 lb. each, have a good-class, close-woven, and clean appearance, contain very little filling (not more than 3 or 4%) and, although not so heavy as some of the poor quality sheets, are very durable, that is, will withstand a great deal of wear and washing.

Examples of poorer qualities of plain cotton sheets are woven from 24's warp, but only 44 ends per inch, and 66 picks of 13's weft; 45 ends of 27's warp and 57 picks of 15's weft; 43 ends of 32's warp and 53 picks of 15's weft. It will be observed that the weft in each of these poorer examples is thicker than the warp; this gives weight and thickness to the fabric, and may even have a fuller handling quality, but the fabric is not as durable. Still poorer qualities of plain cotton sheets are regularly made. For example, 45 ends of 26's warp and 42 picks of 9's condenser or waste weft.

Twill sheets also vary considerably in quality. Twill woven sheets are softer and warmer than plain weave sheets. A superior quality twill sheet consists of 72 ends of 24's and 83 picks of 22's weft. In general, twill sheets usually have more picks than ends per inch and the weft is coarser than the warp. An example of a low quality of twill sheet is 44 ends of 24's warp and 44 picks of 7's condenser or waste weft, making a 2 × 3 yd. sheet weighing about 2¼ lb.

The medium and low qualities of sheets, bleached, usually contain an excessive amount of filling. In such cloths, the simple rubbing action, as when hand washing, dislodges some of the powdery filling, which can be seen to fly out. There may be anything up to 25% of filling in the low-quality sheets, and although it increases the weight and gives the impression of being of better quality than is actually the case, it serves no good purpose so far as wear is concerned. A few washings will remove all such fillings from sheets.

IRISH SECTION—ANNUAL MEETING

The 8th annual meeting of the Section was held at the Municipal College of Technology, Belfast, on Friday, 20th April 1934: Mr. W. H. Webb presided. The Honorary Secretary, in his report, stated that two meetings had been arranged for the beginning of the session, but unfortunately both meetings had had to be cancelled at rather short notice, and it was only possible to procure one other suitable lecture, viz. "Recent Work on the Power Loom", by W. A. Hanton, M.Sc.(Tech.). Two members were added during the year and there were two resignations, the total membership remaining at 35.

It was decided that the Chairman, Hon. Secretary, and Committee be recommended to Council for re-election. The Chairman stated that a further endeavour should be made to increase the membership of the Section and suggested that invitations to attend one of the meetings might be forwarded to a number of firms engaged in the linen industry. These firms could also—in some suitable manner—be invited to become members. With regard to Section meetings for the following session, Dr. Gibson suggested that a paper on "Chemical Engineering" might be welcomed, and said he would endeavour to procure a suitable lecturer. The Hon. Secretary, Mr. F. J. W. Shannon, was instructed to invite Dr. Hampson to deliver his postponed lecture in Belfast during next winter. He was also instructed to ascertain if it would be possible to secure a lecture on "Dyeing"—with some reference to naphthol colours.

MIDLANDS SECTION—ANNUAL MEETING

This meeting was held on the 4th May 1934, at the College of Technology, Leicester, Mr. T. Morley presided over a small but representative attendance.

Mr. T. A. Purt (Hon. Secretary) presented his annual report which showed an increase of 8 members for the year. The programme of lectures for last session proved really interesting, and though attendances were not so large as might have been hoped, yet fairly long journeys were associated with some of the visits to works. He appealed to each member to decide upon definite attendance at one or two of the fixtures each session, as this would ensure satisfactory assemblies. On the occasion of the visit to the Dunlop Works at Erdington, interesting addresses were contributed by Mr. R. Truesdale (Associate) and Mr. T. M. Lawson (Fellow). It was deeply deplored that, since that occasion, the death of Mr. Truesdale, following a short illness, had taken place. The report was accepted, and Mr. Chamberlain observed that in the matter of attendance the widely scattered area covered by the Section was to be taken into account. Regarding visits to works, a suggestion by Mr. Purt that these should take place preferably in summer months was referred to the Committee.

It was agreed to recommend to Council the re-election of the existing Committee. Mr. T. A. Purt was unanimously re-elected Honorary Secretary and warmly thanked for his services during the past year. The programme of meetings for next session was discussed and several suggestions submitted, including the holding of a dinner. Arrangements of the programme was referred to the Committee.

The meeting concluded with a hearty vote of thanks to the Chairman.

LONDON SECTION—ANNUAL MEETING

This was held at the Section Rooms, 104 Newgate Street, on Monday, 7th May 1934, when Mr. A. E. Garrett took the chair. The Committee's annual report, of which a summary follows, was read and approved.

Inter alia the report stated that the London Section during 1933 had lost through resignations, transferences, and other causes, 17 members. In the same period 7 members had been added, making the total membership at 1st January 1934, 119. During the Lecture Session 1933–34 two public lectures had been held. One by the kind permission of the Clothworkers' Company had been held in their hall, and the other in the hall of the London County Council, Barrett Street Trade School. A public lecture arranged jointly with the Society of Dyers and Colourists had also taken place in the hall of the Barrett Street Trade School. In addition six informal Discussion Meetings had been held in the Members' Room at the offices of this Section. The Committee was pleased to be able to report that as a whole the lectures had been better attended this Session and in order that the interest of members might be retained asked for their closest co-operation in the matter of suggestions for 1934–1935 Lecture Session. A very successful party of 18 was organised to visit Mills, etc in the Manchester district during 20/22 September 1933. In this connection the Committee wished to record its keen appreciation of the interest shown and the assistance given by the Council and Headquarters Staff. It was proposed to organise a similar visit to Yorkshire Mills during the autumn 1934. The Special Committee appointed at the last annual meeting had been giving consideration to several proposals having reference to increasing the usefulness of the London Section, and a very carefully considered report had been sent to the Council in Manchester.

The Honorary Secretary reported that 19 nominations had been received and, therefore, no ballot would be necessary. It was unanimously decided that these nominations should be recommended to Council for election to the London Section Committee.

It was unanimously recorded that Mr. John Howard be re-elected Chairman of the Committee for the ensuing year, and thanks were recorded to Mr. Howard for his past services. Messrs. A. E. Garrett, F. Henley, P. J. Neate, and E. Wigglesworth were unanimously re-elected Vice-Chairmen for the ensuing year. Mr. A. R. Down was re-elected Hon. Secretary, and Mr. Albert Gowie, Hon. Assistant Secretary. Thanks were expressed by the Chairman for their continued interest and service.

YORKSHIRE SECTION—ANNUAL MEETING

The annual meeting of members of the Yorkshire Section was held at the Midland Hotel, Bradford, on the evening of 31st May 1934. Mr. T. H. Robinson (Chairman of the Section Committee) presided, and there was a fairly good attendance.

The Chairman stated that Mr. John Robinson, owing to retirement, had resigned membership of the Committee. Over many years past Mr. Robinson had been a most enthusiastic supporter of the work of the Section and of the Institute. On the motion of Prof. Midgley, seconded by Mr. Bailey, it was unanimously decided that the Hon. Secretary should send a suitable letter to Mr. Robinson, expressing regret on account of his withdrawal from Committee, and hearty appreciation of his past services.

The Chairman referred to the membership of the Section and said it was encouraging to note that eight new members had been elected since the commencement of the present year.

It was reported that there were 11 nominations for 10 vacancies on the Committee. It was agreed to ask Mr. George Garnett to attend meetings of the Section Committee in his capacity of Past-President, instead of taking a place on the Committee, and to omit his name from the Committee nominations. The remaining names were then unanimously recommended to Council for election to the Section Committee.

NOTES AND NOTICES

Council of the Institute

At the September meeting of the Council (Mr. F. Wright presiding), there was an excellent attendance for the consideration of many items of interest contained in a somewhat lengthy agenda. The results of the June Examination of the Institute, as submitted by the Board of Examiners, were confirmed and satisfaction was expressed not only on the score of definite increase of numbers, but more particularly on that of the wide geographical distribution of candidates. In view of the greater demands upon the services of examiners, the Council accorded grateful thanks to all concerned in the conduct of the Examination. At the request of the Publications Committee, preliminary consideration was given to the subject of the next Annual Conference, and it was agreed that, for next meeting, this matter should be specially included in the agenda. Meanwhile, it was decided that, subject to final assent to the holding of a Conference in 1935, the policy of covering one general subject in papers contributed should be continued. The subject for next Conference, therefore, will be "Conversion of Fibres into Yarns". The Council also dealt with casual vacancies which had arisen among the Vice-Presidents and the Council. Mr. Henry Binns, of Bradford, was unanimously elected a Vice-President in succession to the late Alderman Wm. Frost. Mr. F. Kendall, of Bradford, was elected to membership of the Council, thus filling the vacancy created by the death of Mr. R. J. H. Beanland. Fitting reference was made to the services of the late Mr. Beanland, and a vote of condolence was recorded.

Honorary Fellowship—Presentation

The Committee of the Midlands Section of the Institute, of which Mr. Tom Morley (Leicester) is Chairman, have decided to hold a Dinner at the Grand Hotel, Leicester, on the evening of Friday, October 5th. The event is arranged in order to provide a social gathering for members of the Section and friends, including ladies. The Council has decided to take advantage of the occasion for the formal presentation of the certificate of the Honorary Fellowship of the Institute recently awarded to Mr. C. F. Topham, of Coventry. Members of Council and other officers have been invited to attend the function; any member of the Institute interested in the event may notify attendance and apply for tickets, the charge for which is 7s. 6d. each. It is hoped that the efforts of the Section Committee in the organisation of the event will receive the fullest possible support.

Examination in General Textile Technology

The Council of the Institute announces that the following candidates passed the Institute's Examination in General Textile Technology, held simultaneously in June last at Manchester, Nottingham, Dunfermline, Belfast, Quebec (Canada), and Calcutta (India)—S. Appleyard (Bury); T. Baker (Bolton); R. C. Boyce (Loughborough); J. V. Davidson (Leeds); W. A. Dutton (Ilkeston, Derbyshire), with special merit; J. Dyson (Rochdale); O. Engelhardtsen (Norway); E. Elliott (Didcot, Berkshire); C. H. Hampson (Westhoughton); A. A. Hayes (Bolton); G. V. Hirst (Bradford); J. L. Holland (Bury); F. G. Holroyd (Bradford); J. H. Maudsley (Quebec, Canada); H. R. Neill (Lisburn, N. Ireland); D. A. North (Halifax); Wm. W. Platt (Oldham); J. H. Riley (Bury); T. Roscoe (Bolton); C. E. C. Wilson (Liverpool).

T. Baker (Bolton) also passed the Examination, Part I (Auxiliary Subjects).

The above-named candidates have now completed the qualification requirements for award of Associateship (A.T.I.).

Institute Members in U.S.A.

It was reported at the September meeting of the Council that Mr. Frank Nasmith, Vice-President, during a recent visit to the United States, had been able to meet a considerable body of Members of the Institute in America. The occasion was a luncheon kindly given by the Universal Winding Company. Twenty members of the Institute attended, along with other guests, and Mr. C. H. Clark, Secretary of the United States Institute for Textile Research, presided. In the course of the proceedings, Mr. Nasmith, after expressing gratitude for the opportunity to meet so many fellow-members, briefly outlined developments in the work of the Institute consequent upon the grant of a Royal Charter. The scheme of professional qualification of members was of the utmost importance and had definitely put "on the map" the profession of textile technologist. Successful applications on the part of members in America for the Institute's Diplomas had been made in several instances. He invited their hearty co-operation in the development of textile technology. The meeting appointed a small committee to draw up a resolution expressing to the Textile Institute, the appreciation of American members for the opportunity of meeting Mr. Nasmith. The resolution, forwarded to Manchester by Mr. Clark, is as follows—

> Whereas the American Members of the Textile Institute, assembled at a luncheon at the Parker House, Boston, Mass., U.S.A., 6th August 1934, have been privileged to have as their guest of honour Mr. Frank Nasmith, F.T.I., Honorary Secretary and a Vice-President of the Textile Institute, be it
>
> Resolved, that we desire to express our deep appreciation of the message that he brought to us, and also of the honour of having for the first time at a meeting of the American members an officer of the Textile Institute. Also, be it

RESOLVED, that we extend greetings to our fellow members in Great Britain, and offer our co-operation in all matters affecting the welfare of the Textile Institute.—(*Signed*) DOUGLAS G. WOOLF, BRACKETT PARSONS, Prof. H. J. BALL, *Committee on Resolutions*, and CHARLES H. CLARK, *Toastmaster of the Meeting and Luncheon of American Members of the Textile Institute in honour of Frank Nasmith, F.T.I.*

The Council expressed warmest satisfaction in regard to the meeting, thanked Mr. Nasmith for his services, and directed that a suitable letter of acknowledgment of the resolution be forwarded to Mr. Clark.

The Late Mr. R. J. H. Beanland

The Institute has suffered the loss of several prominent Members in recent months, and the death of Mr. R. J. H. Beanland, of Clayton West, near Huddersfield, in the latter part of August, has removed a most ardent and active supporter over many years. From the time of the obtaining of the Royal Charter, in 1925, Mr. Beanland became particularly interested in the scheme of qualification of Members and devoted a great deal of time and energy to the work of the Selection Committee, the meetings of which he attended with marked regularity as a representative on the side of industry. Mr.,Beanland was Chairman and Managing Director of the firm of Messrs. R. Beanland & Co. Ltd., Worsted Spinners, Clayton West. Elected a Fellow of the Institute in 1927, his experience in relation to technical education in regard to the textile industry was most advantageous in reference to his duties as a member of the Selection Committee of the Institute. Mr. Beanland also took a warm interest in the annual competitions of the Institute and, in quite recent years, had made considerable effort to secure support for special competitions for students engaged in the woollen and worsted industries. The funeral took place at Scholemoor Cemetery, Bradford, on the 31st August, and was attended by a large body of representatives of textile interests in the West Riding. Institute officers and members were represented by Messrs. Henry Binns, T. H. Robinson, J. Dumville, S. Kershaw, and J. D. Athey (General Secretary).

We have also to record the death in August of Mr. John Ainscow, a well-known cotton manufacturer, of the Beehive Mills, Lostock, Bolton. Although Mr. Ainscow was not directly associated with the work of any Committee of the Institute nevertheless he was a warm supporter of our institution.

Formerly head of the Textile Department of the Burnley Technical College, Mr. James Holmes, who had been retired and resident at Blackpool since 1923, has passed away after prolonged illness. Mr. Holmes was a pioneer in teaching and the conduct of classes in weaving, and it is computed that for thirty years an average of 500 pupils came under his care. A native of Hebden Bridge, he spent most of his life at Burnley and contributed substantially to early literature on weaving subjects.

Special Course for Textile Teachers

A week-end course for teachers of textile subjects at technical colleges and schools was conducted at Loughborough from 7th to 9th September. There was an attendance of about 40 teachers representing the Midlands, Yorkshire, Lancashire and the West of England, and hostel accommodation was provided at the Rutland Hall in connection with the Loughborough College. The course was promoted by the Board of Education, and Mr. H. Salt acted as Organising Inspector, other inspectors present being Messrs. Thorne and Burns. The Chief Inspector, Mr. E. G. Savage, of London, attended part of the proceedings and elicited the views of the teachers in regard to place, subjects, and period for a course next year, opinion favouring a period of one week. The Loughborough course was opened with an address on "The Art of Teaching", by Professor H. A. S. Wortley. The main discussion, covering two half-days, was on the subject of National Certificates in Textiles, the whole scheme being explored in detail. Mr. J. H. Vowler, of the British Launderers' Research Association, contributed a paper on "Laundering Effects" and he appealed for consideration of teachers to features of fabric structure in relation to launderability. Owing to indisposition, Mr. J. E. Dalton, H.M.I., was unable to attend and make a contribution on "Teaching Difficulties". The General Secretary of the Textile Institute attended and during the discussion on National Certificates alluded to aspects of the scheme from the standpoint of the Institute.

Sixth International Congress for Scientific Management

It will be recalled that the Textile Institute accepted an invitation to join the Council of the Sixth International Congress for Scientific Management, which is to be held in London in July next year, under the patronage of H.R.H. the Prince of Wales—Mr. F. Nasmith, Hon. Secretary, accepting nomination as representative. At the Council meeting held on June 28th, under the Chairmanship of Sir George Beharrell, D.S.O., Dr. E. F. Armstrong reported that the Congress meetings will be held in the Central Hall, Westminster, and at the Halls of the Institution of Civil Engineers and of the Institution of Mechanical Engineers (by kind permission of their Councils). He confidently expected that the number of two thousand members who were enrolled for the Paris Congress in 1929 would be exceeded, and that of this number of delegates, at least six hundred would come from abroad. Arrangements were being made for various visits to factories, farms, and institutions, but the only ceremony which had been definitely decided up to date was an Evening Reception in the Guildhall, upon the invitation of the Court of Common Council of the City of London. Sir Henry Fowler reported that amongst those in this country who had agreed to contribute papers upon the practical applications of management in all its phases, were managing directors in a wide range of industries, merchants, prominent agriculturists, and representatives of leading women's organisations. Mr. G. R. Freeman announced that a large number of industrial companies were supporting the Congress, and that a donation had just been received from the Fishmongers' Company.

Gifts to the Institute

Recently an advertisement appeared in the *Journal* asking for certain back issues for 1923. One solitary copy was notified to us and the advertiser secured his full volume as a result. Later, Mr. John Crompton called and gave us a complete set of issues for 1923, several extremely valuable issues of earlier volumes and a few publications of other bodies. Practical assistance and thoughtfulness such as this is much appreciated.

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application—

No. 117—Apprentice Manufacturer desires position as Manager or Assistant Manager in spinning mill. M.A.(Cantab.), Hons. in Engineering. City and Guilds 1st Class Certificates in Woollen and Worsted Weaving, Woollen Yarn Manufacture, and Wool Dyeing.

No. 118—Young man, A.T.I., seeks position as Manager or Assistant Manager in weaving factory. City and Guild Certificates in Linen Weaving and Mill Management. Nine years' factory experience in damask and fancy weaving; five years' research work on weaving and fabrics.

Textile Institute Diplomas

Elections to Associateship have been completed as follows since the appearance of the previous list (June issue of this *Journal*)—

ASSOCIATESHIPS

BANKAPUR, Ramkrishna Nemasa (Dist. Bijapur, India).
DAY, John (Dewsbury, Yorkshire).
NICHOLLS, Kenneth (Sydney, Australia).
PECK, Arthur, jun. (Leeds).

Institute Membership

At the September meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—A. N. Engblom, c/o Boras Wafveri Aktiebolag, Boras, Sweden (Technical Director, and one of the Directors of the Firm); A. R. Harrison, Thornhill, Highfield Lane, Keighley (Worsted Coatings and Woollen Manufacturer); H. Hill, Department of Lands, 64/65 Merrion Square, Dublin, I.F.S. (Organiser for Development of Production of Handwoven Tweeds); I. H. S. Mattar, Chemical Department, Cairo, Egypt (Chemist, Textile and Paper Section); J. Noguera, 27 Blackfriars Street, Salford 3 (Director, Casablancas High Draft Co. Ltd.). *Junior*—J. J. Duncan, 65 Haywood Road, Mapperley, Nottingham (Student, Nottingham University College); T. M. Woo, College of Technology, Sackville Street, Manchester 1 (Student).

REVIEWS

The Worsted Industry. By J. Dunville and S. Kershaw. Published by Sir Isaac Pitman & Sons Ltd., 3rd Edition. (168 pp., Price 3/-).

Without delving too deeply into details the book covers the whole of the worsted industry from the origin of the fibre to the finished fabric. This edition should prove to be a very handy volume for those wishing to gain a general knowledge of the industry, since much valuable material relating to important developments is incorporated for the first time. The additions include a worsted calender; diagrams showing worker, stripper, and fancy actions; and information on the square motion comb; the intersecting gill box; the Anglo-Continental drawing machines; the mule ring frames; and the production of fancy yarns. A very useful bibliography for the student is the final recent inclusion. One or two points may be criticised. In the diagram illustrating the action of the fancy, the clothing is too deep in mesh. In another newly-added diagram, this time of the square motion comb, there are many reference letters and numbers which are not mentioned in the text. In the chapter "Cleansing Wool", the only references to the possibilities and dangers of the wool felting are made in the drying stage, and yet possibly the most serious causes for such entanglement and matting of fibres, are to be found in the bowls and at the squeeze rollers. In Chapter VII the two sentences on p. 79 referring to the effect of draft on twist might be misleading. Twist being "re-imposed" and repeatedly added and withdrawn, suggests that untwisting takes place at some stage. Turns per unit length are reduced by attenuation, but the total twist is always being increased and never suffers appreciable reduction. The book is well written and illustrated by clear diagrams and photographs of machines. Probably the chapter on Parallelisation is the most worthy of commendation and in particular the sections describing the principles of the very complicated combing mechanisms. An appendix is written by Robert Taylor on the Fire Hazards of Worsted Mills. S. T.

Fourteenth Annual Report of the Industrial Health Research Board to 30th June 1934. Printed and Published by H. M. Stationary Office, London, 1934. (Price, 9d. net.)

The Introduction to this report, though lacking in simplicity of language and somewhat, too, in punctuation, should be widely read. It reveals the magnitude of the task to which the Board has set its hand and some, though by no means all, of the difficulties to be faced. To read that the Board realises its "lack of knowledge about the physical condition of the working population as a whole", is to realise also something of the size and number of the problems to be attacked. It is gratifying to learn that mental fatigue is receiving its due attention and to see the name of an eminent psychologist has been added to the Board. Might it be suggested that to learn something of the physical condition of the working population goes, or should go, hand-in-hand with a knowledge of the physical condition of the child just about to leave school ?

Part III of the Report—Investigations—describes the Board's work under the heads of environmental conditions; physiology and psychology of work; sickness and absenteeism; and vocational suitability. Though only in one or two cases directly textile in character, the investigations described are indicative of work along definitely productive lines and one or two reports, when available, will be referred to in more detail. Altogether a satisfactory position is revealed. It is a pity that the "official" atmosphere of a Government body produces such stilted language and long-winded sentences. T.

Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry, 1933, Vol. XVIII. Published by the Society from its offices in Finsbury Square, London, E.C.2. (710 pp. with name and subject indexes. Price to members 7s. 6d., and to others 12s. 6d.)

These invaluable reports constitute an example that might well be followed by other similar organisations. It may be claimed that practically every separate report has points of interest to textile technologists with perhaps the exceptions of those dealing with Soils and Fertilisers, Medicinal Substances, and Sanitation, but so catholic are the interests of the textile industries, or at least should be, that even these sections might profitably be read. On the other hand the reports on "Colouring Matters and Dyes" by E. H. Rodd and H. A. Piggott; "Textiles, Fibres, and Cellulose" by J. C. Withers; "Bleaching, Dyeing, Printing, and Finishing" by J. B. Speakman; "Oils, Fats, and Waxes" by T. P. Hilditch; and "Sugars, Starches, and Gums" by L. Eynon and J. H. Lane should be generally read. It is not known to what extent previous volumes in this series are available, but there can be little doubt that the series is valuable and will continue to increase in demand as a source of reference and as its existence and purpose become more widely known. T.

The Jubilee Issue of the Journal of the Society of Dyers and Colourists. Published by the Society at the General Offices, 32 Piccadilly, Bradford. (227 pp. Price, to non-members, 25s. per copy.)

This Society celebrates its fifty-year jubilee in 1934 and the volume of which this is a notice has been issued in commemoration of the event. Whilst by no means to be compared in age with Societies such as the Royal Socety, founded 1660; or the Royal Geographical Society, and the British Association for the Advancement of Science, both in 1831; yet of organisations associated definitely with industry the Society of Dyers and Colourists is among the oldest and most widely known. It would not perhaps be too much to say that probably no other analogous society has so close a contact with any specific industry. A list of its members and of its office-bearers would serve with little alteration or addition as a list of the leading makers, users and scientists concerned with dyestuffs of the past half-century. The contents of this jubilee number consist of original articles, some being reviews of 50 years' progress and others dealing chiefly with the present state of knowledge of the subjects under consideration. Perhaps the best service a reviewer can render to this publication is to give a list of its articles and authors who as the "Editorial" says "are too well-known to need . . . introduction and have been, or are, actively and intimately concerned with the subject of their articles". The list is as follows—"The Romance of the Society of Dyers and Colourists" by George G. Hopkinson (Honorary Secretary of the Society); Early History of Dyeing" by J. Huebner; History of the Worshipful Company of Dyers, London" by A. H. Brewin; "The Constitution of Cellulose" by W. N. Haworth; "The Constitution of Animal Hairs" by W. T. Astbury and J. B. Speakman; "Reactions for the Detection of Damage or Irregularities in Textile Fibres" by P. Krais; "Landmarks in the Evolution of the Dyestuff Industry during the Past Half-century" by A. G. Green; "Substitution in the

Benzene Nucleus" by R. Robinson; "The Relation between the Constitution and Substantivity of Dyes" by P. Ruggli; "British Patent Laws, Ancient and Modern" by H. Levinstein; "A Review of Cotton Bleaching" by W. Kershaw and F. L. Barrett; "Some Outstanding Events and Methods in the Commercial Application of Dyes on Cotton and Allied Fibres" by A. Singer; "The Dyeing and Finishing of Cotton" by F. Scholefield; "Progress in Calico Printing" by J. B. Fothergill; "The Dyeing of Rayons" by C. M. Whittaker; "Slubbing and Wool Yarn Dyeing" by E. Isles; "Half a Century in the Dyeing and Finishing of Worsted, Woollen, and Union Piece Goods" by W. S. Stansfield; "Hosiery Dyeing and Finishing 1884-1934" by W. A. Edwards and G. F. Hardcastle; "A Survey of the Dyeing Printing, and Finishing of Natural Silk" by G. Tagliani; "Dry Cleaning, Wet Cleaning, and Dyeing" by F. W. Walker; "Fur Dyeing" by T. R. V. Parkin; "The Dyeing of Leather" by T. H. Wilson; "The Chemistry and Technology of Rubber and Synthetic Resins" by W. J. S. Naunton and F. J. Siddle.

It may perhaps be permitted to wish the Society a prosperous and equally useful progress to its Centenary. T.

British Association for the Advancement of Science. Report of the Annual Meeting at Leicester, 1933. Published by the Association at Burlington House, London W.1.

In addition to the Presidential address by Sir F. G. Hopkins, and the Section President's addresses, this volume contains two valuable reports by Committees appointed by the Association. The first is on "General Science in Schools" and the second constitutes an "Inland Water Supply". In the Section Transactions, abstracts of the papers presented are printed, and of these the following are of interest—"Some Recent Developments in the X-ray interpretation of the Properties of Hair, Feathers, and other Protein Structures" by W. T. Astbury; "Fibre Chemistry and X-ray Analysis" by J. B. Speakman; "The Chemistry of Quebracho Tannin" by P. Maitland; "Economic Theory of Patent and Copyright Law" by A. Plant; "Organisation as a Technical Problem" by L. Urwick; "The Practical Value of Physiology to Industry" by G. P. Crowden; The Legal Aspect of River Pollution" by H. F. Atter; and "The Hosiery Industry" by J. Chamberlain. In addition, Sir Josiah Stamp delivered an evening discourse "Must Science Ruin Economic Progress?" which is fully reported. T.

GENERAL ITEMS AND REPORTS

P.E.P. (Political and Economic Planning) Industries Group. Report on the British Cotton Industry. Published from the Offices of P.E.P., 16 Queen Anne's Gate, London S.W.1.

Three major points come to mind on reading, even cursorily, this report. Firstly, that every Lancashire man ought to read it and would probably get very wroth in the process. Secondly, that no other survey of the causes of and the present position in Lancashire yet exists which is anything like so comprehensive. And thirdly, that to attempt a critical or even a descriptive survey of the report would involve quotation of nearly half of it and is therefore out of question in this *Journal*. It must suffice to detail its contents and to refer to one or two points of specific interst to those whose concern is textile technical education and/or textile research.

Fourteen pages are devoted to the Introduction, which amounts to a short summarisation of the facts and figures accumulated in Part II—The Survey. Proposals for reform are put forward in Part III—Reorganisation. Part IV deals with the Cotton Industry in other Countries. The survey covers the Extent of the Depression, Causes of the Depression; Markets; Purchase of Raw Cotton; Spinning; Weaving; Finishing; Marketing; Labour; Plant and Equipment; and Research.

The point is made that "Lancashire has failed to move forward in structure, organisation, and technique". How true this may be in many respects cannot be discussed here, but so far as educational and research organisation is concerned there can be no hesitation in affirming that this country is well ahead of its competitors. If, as may be urged and as had been urged by those in a position to know, the cotton industry does not avail itself any too readily of the advantages of its educational and research facilities, that is a fault that can be easily remedied. The report itself says "the technique of utilising research is not well developed in the British cotton industry". It may be that seeming neglect is almost entirely due to the harassing and pressing incidence of economic and financial problems. The report continues that "it cannot be overestimated that an apparently dying and nearly bankrupt industry does not attract good and young men". Whether this be true or not is perhaps a moot point; it seems to have been overlooked that many men who would now be in their forties and who would have been giving the best years of their lives to the industry were killed in the war. The Introduction concludes with the statement that "Any proposals will be jeopardised if a scientific and factual approach is not adopted in trying to put them into effect". If this may be interpreted into a plea for the application of the scientific spirit and method to textile economics it can be heartily endorsed. This form of research has, it would appear, been too long neglected. In this connection the report urges "research from the consumer's angle", and further states that "insufficient attention has been devoted to the question of economic research and the collection of statistical data".

P.E.P. are unhesitatingly to be congratulated upon this report. It may well be that each and every paragraph could be challenged and profitably discussed. But there can be no doubt as to its comprehensive character which enables the broad outlook to be maintained in the discussion of any of the details of the pressing Lancashire problems. There can also be nothing but commendation of its courage and of the message it bears to Lancashire to "pull together" and sink "internal, often personal, dissensions". T.

Specialised Courses in Advanced Chemistry, 1934-1935.

These courses have been arranged by a Committee appointed by the Yorkshire Council for Further Education in 1933. The scheme proposed has been approved and will be provided by the Local Education Authorities concerned at the Bradford, Huddersfield, and Leeds Technical Colleges in the Session 1934-1935. The booklet describing these courses, published by the Y.C.F.E., refers to the Objects of the Scheme in terms which cannot be improved upon and these are therefore quoted here—

> Owing, however, to the very wide curriculum now necessarily covered in the training of chemists, one very serious difficulty is found, not only by senior students and young graduates of our Technical Colleges and Universities, but also by experienced chemists already engaged in industry, namely, that of keeping abreast of the latest developments in the theory and technique of special branches of the subject; to realise this, one need only quote the developments in recent years of the theories of organic chemistry, microchemical analysis, and electrometric methods of analysis and control.
>
> New discoveries are recorded in the first instance in scientific technical journals, but it is generally a matter of many years before they find a place in students' textbooks or manuals. It is, however, important that information regarding new discoveries and their applications should be made available to technical chemists as soon as possible.
>
> At the same time the number of potential students in a single section of the subject is necessarily limited and they will be scattered over a considerable area. It is, therefore, not possible to provide courses of instruction either every year or at more than a few centres.
>
> It has been long felt that there is a definite need for suitable short specialised "refresher" courses to be given by experts in convenient centres. Such courses are intended primarily for chemists who already possess qualifications equivalent to a University degree, the Associateship of the Institute of Chemistry, the Higher National Certificate in Chemistry, or Final Certificates of the City and Guilds of London Institute. It is hoped that the courses outlined in this pamphlet will help to meet a real need.

A brief list of the courses arranged is as follows—

Courses at Bradford.

i—Practical Work in the Microscopy of Food and Drugs. ii—Recent Advances in Textile Chemistry.

Courses at Huddersfield.

i—Chemical Engineering. ii—Recent Advances in Synthetic Organic Chemistry.

Courses at Leeds.

i—Modern Analytical Methods. ii—Modern Theories of Organic Chemistry.

T.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXV OCTOBER 1934 No. 10

PROCEEDINGS

Midlands Section

DINNER AND PRESENTATION OF CERTIFICATE OF HONORARY FELLOWSHIP

At a dinner promoted by the Midlands Section of the Textile Institute, and held at the Grand Hotel, Leicester, on the evening of Friday, October 5th, the chief item of the proceedings was the presentation of the Certificate of Honorary Fellowship of the Institute to Mr. C. F. Topham, of Messrs. Courtaulds Limited, Coventry. The award was in recognition and appreciation of the valuable contributions of the recipient to the textile industry. Mr. Topham's invention of the centrifugal spinning-box for the twisting and coiling of filaments of artificial silk formed a decisive factor in production on factory scale.

The chair was occupied by Mr. Thomas Morley (Leicester), Vice-President of the Institute and Chairman of the Midlands Section Committee, who was supported by Messrs. C. F. Topham (Coventry) and F. C. Topham (London); H. L. Johnson and G. S. Heaven (Messrs. Courtaulds, Coventry); F. Nasmith, Vice-President (Manchester); W. Kershaw, Chairman of Publications Committee (Manchester); W. Howarth, Member of Council (Bolton); J. D. Athey, General Secretary (Manchester); P. A. Bentley (Leicester), J. Chamberlain (Leicester); W. Pritchard (Derby); H. F. Lilburn (Leicester); E. M. Walker (Nottingham); and T. A. Purt, Honorary Secretary, Midlands Section (Leicester); members of Midlands Section Committee. Many other members attended and several accompanying ladies were present.

Introducing Mr. C F. Topham to receive the Certificate of Honorary Fellowship of the Institute, Mr. H. L. Johnson said—"It is with real pleasure that I rise to present Mr. Topham. Amongst my earliest memories of life are visits to Courtaulds factory at Coventry, where I was—as a boy is—thrilled by the boilers and the big Robey steam engine, but the things which amazed me were the spinning machines. How a machine could turn a liquid into a solid passed my comprehension. I was fed rayon continuously in increasing doses, so that now it has become my only interest in life. And I look up to Mr. Topham as being one who has done so much to make the industry possible, and to provide that interest.

In those early days, the machines had the same pumps to bring up the viscose, candle filters, spinning jets, glass rollers, glass traverse funnels, and spinning boxes devised by Mr. Topham, as we use to-day. The machines have grown in size and length. Dozens and scores of threads have given way to scores of thousands, but the essentials are the same.

As was usual with his generation, Mr. Topham started work at an early age, and shortly after the time that his years reached double figures, he was almost an expert glass blower. As his skill improved, he became a real artist, and with his burner and blowlamp made, literally, pictures in glass.

Later he became associated with Mr. Stern and made the first incandescent electric lamps in this country and in many countries abroad. Years after, his skill in lamp-making led him to take an interest in radio. I remember once discussing with him the trouble with my crystal set, and then asked him how his big valve set was working. He replied that he was not satisfied with its performance and would go home that evening and make a new set of valves, which he did. It was his glass-working skill and the difficulty of making filaments for the lamps that roused his interest in viscose and opened a new field for his genius.

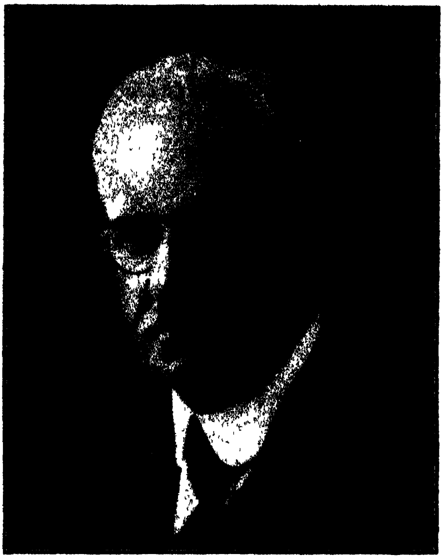

Photo by] [*Nuva, Coventry*

Mr C. F. Topham

He is a man simple minded and sincere, one of whom, as with the Jester in "As You Like It", it may be said "the strange corners of his mind are crammed with observations". His particular genius is the practical application of odd ideas and the putting together of miscellaneous facts. I will give a simple illustration. It was known to many that a young viscose was soluble in acetic acid, and that an old viscose was insoluble in water. Yet it was left for him to piece these two facts together and find that if the viscose was just soluble in both liquids it was at a suitable age to be spun.

But it is the spinning box which is his real masterpiece. In every previous kind of textile operation the thread was always wound on the outside of the container. Cotton, wool, or silk, with mule, flyer, or cap, the yarn was put on the outside of the bobbin. This being unsuitable for the weak and slimy viscose thread, Mr. Topham thought of putting the thread on the inside of the container and thus was born the spinning box which is now in use in nearly every country in the world where rayon is made.

Mr. Chairman, ladies and gentlemen, I have the honour to introduce to you Mr. C. F. Topham."

The Chairman, in handing the Certificate to the recipient, offered warmest congratulations.

Mr. C. F. Topham made brief acknowledgment, and Mr. G. S. Heaven formally replied on his behalf, as follows—"It is with great pleasure that I express the thanks of my modest colleague, Charles Fred Topham, to the Textile Institute for the great honour you have conferred upon him, an honour which has been enhanced by the kind introduction given to him by Mr. H. L. Johnson. Mr. Topham is proud to feel that you have found him worthy to be coupled with that distinguished scientist Charles Frederick Cross, who not only discovered the viscose process, but served as a pioneer of its many applications. Mr. Johnson has given you an outline of his career, and I propose to limit myself to the part played by your new Honorary Fellow in placing viscose rayon upon a footing which enabled it to be commercially useful.

From 1892, when Cross published his discovery to the world, very early efforts were made to use viscose in the paper and textile industries, mainly in the direction of coatings and sizings for paper and fabrics. The textile industry was then as now alive to the possibilities of new processes.

In August, 1893, A. D. Little, who was technical adviser to the group which founded the American Viscose Co., wrote asking his friend Cross what he had done towards getting his (viscose) solution substituted for the one employed by Chardonnet. 'I have made a few experiments which indicate it can be done.' So that viscose silk was very early in mind and any suggestions made in later years were belated.

The Viscose Syndicate founded in 1894 was actually pushing the investigation and use of viscose, and in January 1897, we find Stearn entering into business relationships with Mr. Cross and the Syndicate. The Syndicate opened an experimental laboratory at Station Avenue, Kew, in 1897, and there Stearn, Woodley, and J. F. Briggs, made investigations which supplemented the work of Cross and other investigators in establishing that hitherto unknown thing—the chemistry of viscose. In 1898, Stearn patented his spinning bath of ammonium chloride, and 1899 the Viscose Spg. Syndicate was formed, with Mr. Cross as Chairman, and Stearn as Director.

During this time Mr. Topham was managing the factory of the Stearn Lamp Co. and made visits to Station Avenue; one of his early and welcome suggestions was that of steeping the wood pulp sheets in caustic soda in an upright state, instead of horizontally, thus allowing the escape of air due to the expansion of the pulp, and this permitted a more uniform attack of the soda. Mechanical tearing of the steeped pulp; multiple glass jets, to be later followed by our present multi-holed metal jet; filter candles; etc. followed. In short, numerous mechanical improvements were evolved as a result of Mr. Topham's visits.

To prepare the ground for the invention of the box, I want you to visualise the method then employed for viscose spinning, which was being done at Kew only. Viscose made from materials very uneven in quality was filtered, placed in a bottle and pushed by air pressure through a filter, hence through a jet into a spinning bath of ammonium chloride. This bath precipitated the viscose into filaments which were composed of cellulose xanthate and not cellulose. Thus they were soft, tender, and sticky, and in this condition they were collected on a roller or bobbin. The threads were then heated, steamed, and afterwards set by boiling in strong brine, washed, and dried. The removal of such threads was very difficult, the filaments of the thread, of course, were parallel wound, and it was difficult to pull all of them off at once, as was essential if a good skein was to result. You can imagine the many trials, tribulations, and disappointments of all concerned. Stearn maintained his driving force; knowledge was being accumulated but success seemed far distant.

Even the energy of that optimist, Stearn, eventually flagged and he went with his troubles to Fred Topham—the crux of the problem was to get skeins of a reasonable length. Sitting in his small office in the Stearn lamp factory, Mr. Topham pondered over the problem, conjuring up a picture of the whole operation, chemical methods of preventing sticking he had tried, so he thought only of mechanical methods. In all his many experiences textile operation had no place, so that textile practice neither aided nor hindered him in solving his first problem—that of twisting these slimy filaments.

In his mind he pictured a bobbin revolving on a plate which itself rotated. 'Yes, that would do', his thoughts ran, 'but how can I put the thread on the revolving bobbin ?' The bobbin faded out of sight and he saw the rotating plate only, with the filaments dropping directly upon it. In this he had the solution. A Day and Martin blacking tin was soon procured—this was in the days of a more generous helping of blacking—and was soldered to a rod, mounted with a band drive. A bobbin or tube of viscose silk was wetted and mounted high above the tin, then passed over a pulley. The small motor was put in motion, the end of the thread was rolled into a ball and thrown through a half-inch hole in the lid into the tin, where it vanished, and the thread ran continuously from bobbin to box, of which the speed was 3000 r.p.m. When the run was finished the yarn was found to be coiled and twisted in the form of a cake.

Stearn was mystified when he saw the result, but quickly realised its importance; boxes 6-in. diameter and of increasing depths from ½ in. to 3 in. were made. With the deeper boxes another problem presented itself—that of laying the thread the whole depth of the box. A glass funnel, which lifted and dropped the depth of the box was the solution, so that in one and the same moment the thread was twisted and coiled in the form of a hollow cylinder, within the rotating box.

Further work was intensively pursued by Mr. Topham at the lamp works, and the spinning pump, filter candle and jet, box and reciprocating funnel, soon were made into the ancestors of the present-day large spinning machine. Thus was born what Mr. Cross has described as a comprehensive solution of the main difficulties which had been encountered.

When the process was taken over by Messrs. Courtaulds, Mr. Topham returned to his lamps. But in 1921 he came to Coventry, and he wishes me to say that his time with Courtaulds has been the happiest in his long life. He still ably justifies his position, and does his share in the work of a large organisation. Still with a fertile brain, with hands that may have lost a little of their cunning, he sees in this wonderful appreciation of his contribution to the rayon industry a greater reward than he ever dreamed of."

Mr. F. Nasmith proposed the toast of the "Midlands Section of the Textile Institute", coupled with the name of the Chairman, Mr. T. Morley. He said he regarded the Midlands Section as a healthy and progressive branch, and the Section had undoubtedly been most fortunate in securing the services of devoted officers and members of Committee. To advance the cause of textile technology meant uphill work, but industrialists were more and more recognising the value of attainment in the form of the Institute's qualifications. In connection with the recent examination of the Institute—General Textile Technology—a candidate from the Midlands passed with distinction.

The Chairman and Mr. J. Chamberlain responded. Mr. Morley said he would always be pleased to render all possible assistance, whilst Mr. Chamberlain mentioned that the Midlands Section was now in close co-operation with headquarters, having three members of Council, three of Selection Committee, and a fair share of Associates and Fellows within the Midlands area.

Congratulatory messages were read from Sir Thomas Robinson, K.B.E., President of the Institute; Mr. Samuel Courtauld, Chairman of Messrs. Courtaulds Limited; and Mr. C. F. Cross.

Sir Thomas Robinson expressed great regret on account of his inability to attend, because, he stated, "I was exceedingly anxious to associate myself with the recognition of the services of Mr. C. F. Topham".

Mr. Samuel Courtauld wrote—"We should like to take the opportunity of telling you how very much pleased we are to know of the honour which you are conferring on Mr. Topham. He has been associated with us in the rayon industry from very early days, and we feel assured that no man concerned with it could be more worthy of the honour".

Mr. C. F. Cross stated—"I read with great pleasure of the award of the Honorary Fellowship to C. F. Topham. This represents not merely the new textile, but a recognition of Mr. Topham's great work and achievements for the establishment and propagation of the industry to its world-wide dimensions".

NOTES AND NOTICES

Institute's Annual Competitions

Entries for the current year's Competitions of the Institute in relation to the design and structure of woven fabrics, knitted fabrics, fancy yarns, and designs for printing of fabrics, are now closed. The Competitions Committee will meet on Friday, October 26th, to complete arrangements for adjudication and to consider the prospectus for the 1935 competitions. In the latter connection, an interesting announcement has recently appeared in the public Press to the effect that a legacy of £1,000 has been provided by the provisions of the will of the late Mr. R. J. H. Beanland, of Clayton West, near Huddersfield. It is stated that the income from the amount stated is to be devoted to the provision of prizes in connection with the production of worsted cloths or yarns. When available, the income will undoubtedly help the Competitions Committee in regard to the comprehensiveness of the prospectus. The date of the presentation of prizes and display of exhibits in connection with the 1934 competitions has already been fixed to take place at the Institute premises, Manchester, on Saturday, December 8th, and the exhibition will be open over Friday, December 7th.

Midlands Section Dinner

The decision of Council to include in the proceedings of the social gathering held by the Midlands Section of the Institute, on the evening of October 5th, the presentation of the certificate of award of the Honorary Fellowship to Mr. C. F. Topham, proved most appropriate. The company present, though not large, was representative. The award of Honorary Fellowship to Mr. Topham has met with abundant and widespread approval. The communications received from Mr. Samuel Courtauld (Chairman of Courtaulds Ltd.), Mr. C. F. Cross (previously awarded the Honorary Fellowship), and Sir Thomas Robinson (President of the Institute) expressed sincere and gratifying appreciation of the honour conferred upon Mr. Topham. A record of the presentation ceremony appears in this issue. Mr. T. A. Purt, Hon. Secretary for the Midlands Section Committee, made excellent arrangements for the event—the first of the kind to be promoted in connection with the Section.

Obituary Announcement

Fellow and Life Member of the Institute, Mr. M. C. Andrews, of Belfast, passed away after a brief illness on the 3rd October. A highly-esteemed member of a family closely associated with the Irish linen industry for well over a century past, Mr. Andrews was best known as a director of the firm of Messrs. John S. Brown & Sons Ltd., linen manufacturers. From 1929 to 1931 he was Chairman of the Irish Power Loom Manufacturers' Association. Mr. Andrews took the warmest interest in the welfare of the Institute, and many members have enjoyed the privilege of visiting the mills of his firm—St. Ellen Works, in the Belfast area.

Institute Employment Register

The following announcement is taken from the entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application—

No. 119—Young man (A.T.I.) seeks position in hosiery factory. E.M.E.U. Certificates in hosiery manufacture, dyeing and finishing, and Group Certificate in textiles. Ten years' experience in underwear, outerwear, and swimming costume trade; testing laboratory experience. Age 26 years.

No. 120—Production manager (B.Sc.Tech.) in Warp Knitting seeks similar post; experience of various types of machinery.

- -

An inquiry (Box S.A., c/o Textile Institute) has been received for services in connection with the operation of jacquard looms for manufacture of woven labels, blazer badges, etc. Applicants would be required to take charge of a factory in South Africa, and a contract for one year or longer, with payment of passage etc., is proposed.

Textile Institute Diplomas

Elections to Associateship have been completed as follows since the appearance of the previous list (September issue of this *Journal*)—

ASSOCIATESHIPS

APPLEYARD, Sidney (Bury).
BAKER, Tom (Bolton).
BOYCE, Richard Cecil (Loughborough).
DAVIDSON, James Vernon (Leeds).
DUTTON, William Albert (Ilkeston, Derbyshire).
DYSON, Jack (Rochdale).
ELLIOTT, Ernest (Didcot, Berks.).
ENGELHARDTSEN, Olaf Christian (Norway).
HAMPSON, Cyril Herbert (Westhoughton).
HIRST, George Victor (Bradford).
HOLLAND, James Lewis (Bury).
HOLROYD, Frank Gullon (Bradford).
MAUDSLEY, Jack Heald (Quebec, Canada).
NEILL, Henry Reginald (Lisburn, Ireland).
NORTH, Douglas Abram (Halifax).
PLATT, William Wild (Oldham).
RILEY, John Henry (Bury).
ROSCOE, Thomas (Bolton).
WILSON, Charles Ernest Coleman (Liverpool).

COMMUNICATIONS

"The Dermatergoses or Occupational Affections of the Skin, giving Descriptions of the Trade Processes, the Responsible Agents and their Action"

To the Editor

SIR

You will probably be aware that a Committee of Dyestuff Manufacturers and Colour Users has been formed to consider the best method of dealing with the question of alleged dye Dermatitis arising from the wearing of textiles.

In your August issue there appears a review on Dr. Prosser White's book on Dermatergoses, in which review the following statement appears—

> "Many of the chemicals used in the bleaching and finishing industries are liable to affect the skin, and in dyeing and calico printing the aniline dyes are a frequent source of disablement; indeed, so many likely materials used in the textile trades are irritating to the skin . . . ."

whereas in another review the following quotation from Chapter IX of the book itself appears as follows—

> "though synthetic dyes have been suggested as responsible for local irritant action, this has not been sufficiently proved except for a few . . . ."

This last sentence appears to be in contradiction to part of your reviewer's statement quoted above.

The Committee regret that your reviewer has neglected to point out that modern medical opinion is becoming increasingly appreciative of the part that personal idiosyncratic and allergic conditions play in the incidence of dermatitis—occupational or otherwise.

The combating of dermatitis claims alleged to be due to the wearing of textiles is sufficiently difficult without a statement similar to the above appearing in a journal devoted to the interests of the textile trade. My Committee, therefore, hope that you will see your way to make it clear to your members that the opinions in the review are personal to the reviewer, and must not be considered to be those of the Textile Institute.

DROYLSDEN
MANCHESTER 8/10/1934

Yours truly (Signed) C. M. WHITTAKER
Acting Secretary of the Dermatitis Committee

This letter is published in response to the request contained therein and it is to be recorded that the opinions of all reviewers are their own and not necessarily those of the Textile Institute—EDITOR.

"Modern Fabric Structures in the Scottish Woollen Trade"

By D. R. Christie, A.T.I.
(Peter Anderson Ltd., Galashiels)

To the Editor

Sir

In the discussion following the above paper read at the Annual Conference of the Textile Institute by Mr. Christie (*J. Text. Inst.*, June and July 1934, P177 and P324), Mr. Guilfoyle Williams drew attention to a possible limitation of the use of "Lastex" yarn when applied to furnishing fabrics and materials for out-door use generally.

The lecturer, in reply, stated that the core was well protected by a number of covering yarns, and that no trouble should be expected from such uses of "Lastex" yarn.

As Mr. Christie's assurances seem rather in conflict with the evidence obtained by Mr. Williams from an actual experiment with some cloth containing "Lastex" yarn, it was thought that some notes on the resistance of "Lastex" yarn to sunlight might help to clarify the position.

While it is true that the covering yarns afford very considerable protection to the elastic core of "Lastex" yarn, it is nevertheless also true that sunlight would have a certain deleterious effect on that core, should exposure be allowed to take place. The Lactron thread which forms the core must not be judged on the old standards of daylight ageing obtaining for thread made by cutting rubber sheet.

"Lastex" yarn constructions embrace a number of different core cross-sections, obtained either by altering the core stretch or employing a core of different basis gauge, but irrespective of the manner in which the ultimate core diameter is produced, the greater the cross-section, the more resistant is the core to the influence of the sun's rays.

The type of yarn, the number of ends used, and the closeness and mode of winding employed in covering the core all have their effect on its daylight resistance, and if finished gauge and stretch are not too strictly limited, it is comparatively easy to design a "Lastex" yarn of more than ample resistance to sunlight exposure.

Thus there are a number of standard constructions of "Lastex" yarn which will withstand prolonged exposure to sunshine even when in the stretched condition, and without being in any way protected by associated fabric.

Other constructions which by means of gauge limitations, must consist of a finer gauge of core and a lighter form of covering naturally have a correspondingly lower resistance to sunlight, but these may satisfactorily be employed in outdoor and similar fabrics provided that some care is taken in the manner in which they are incorporated.

Optimum results are obtained with such constructions when the "Lastex" yarn is well buried in the associated fabric.

The fact that it is now possible to use elastic yarns in furnishing and outer garment fabrics is in great part due to the superiority of Lactron thread—the core material of all "Lastex" yarns—over the older type of cut thread. Lactron thread has more than four times the life of a good grade of cut thread of similar cross-section when both types of thread are exposed to sunshine in the uncovered condition and under tension.

The superiority of Lactron thread may be ascribed to its method of preparation, which involves a minimum disturbance of the natural structure of the rubber; to the incorporation in the thread of chemical substances which combat the deteriorating action of heat and light, and to the circular section of the thread which exposes a minimum surface for a given cross-section of rubber.

We should be only too glad to go more fully into the question with any interested party as far as his own lines are concerned.

(Signed) Robert G. James
For Lastex Yarn and Lactron Thread Ltd.

London, 4/10/34

GENERAL ITEMS AND REPORTS

THE GEOGRAPHICAL BASIS OF THE WEST PENNINE SILK INDUSTRY

By C. L. Mellowes M.A.(London)

(Principal Geography Master, Burnage High School for Boys, Manchester)

The earliest official reference to silk as a manufacture of the British Isles occurs in an Act of Parliament of 1363, but silk does not figure in the activities of the West Pennine towns until some four centuries later. It was through the use of silk in the button trade that Leek, Macclesfield, and Congleton first became acquainted with silk. The names of button men are noticeable in the records of Leek in the seventeenth and eighteenth centuries, *e.g.* 1702 Thomas Needham; 1702 Thos. Sutton and Mrs. Jane Hayne. At Macclesfield, "this manufacture (of buttons of silk and mohair) was the staple of the town for ages. . . . . About a century ago an Act of Parliament obtained in favour of the silk-button manufacture at Macclesfield, by which individuals were prevented, by a severe penalty, from wearing buttons of the same material as the coat".[1]

Originally the thrown silk for use in the West Pennine button trade came from London. Then small machines for winding silk and making twist were invented and established in this region. As early as 1735 there was a small mill at Macclesfield, belonging to Mr. Daintry, who carried on silk winding and twisting. It was not unnatural that an occasional silk weaver should appear either from London or from Coventry, where there were ribbon weavers. These seem to have been English rather than French or Flemish; *e.g.* in the records of Leek there appear the names of John Bagnall 1658, Daniel Leigh 1684, and Paul Adams 1697. The stage was drawing near when the silk industry in England was to become an English one, carried on by English workers rather than, as it had been originally, a French industry carried on by the French in exile in England.

It has been stated that the silk industry in Leek owed its origin to some Huguenot refugee silk workers who had settled in that town.[2] This statement is based on the following quotation from the Parish Registers—"Collected then for the ffrench Protestants in the parish of Leek in ye county of Stafford, the sum of £6 5s. od., June 21, 1686. George Roades, Vicar".

In the records this notice is preceded by the word "brief". This indicates that the collection was made by a special order or brief from the Bishop. Such an order would apply equally to all the parishes in the diocese. Thus the collection is no proof that French Protestants were resident in Leek. At least three such briefs for the relief of the French Protestants were made during the seventeenth century in response to representations made to the King on behalf of the refugees. When the difficulty of communication in the sixteenth and seventeenth centuries is taken into account, it seems very improbable that refugees from the Continent would penetrate so far north. On the map, Fig. 1, the absence from the north and west of England of churches founded by French and Walloon refugees in the sixteenth and seventeenth centuries is striking.[3] J. Smiles also gives a list of the more notable Huguenot refugees and their descendants, and in this there is no name from Leek, Macclesfield, or Congleton.[4] It seems reasonable, therefore, to conclude that the development of the silk industry in the West Pennine towns was not due to the settlement of refugees in any of these towns. When the silk industry came to these towns the craftsmen were English. Free, to a large extent, from the foreign influence which was so strong in Spitalfields, the West Pennine towns became the English silk towns and developed an individuality of their own. Thus the beginning of the eighteenth century found the West Pennine region simply a market for some of the thrown silk from London. This silk was used primarily by the button men and, in very small quantities, by the few weavers found in the region.

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[1] Aikin, J., "A Description of the Country for Thirty to Forty Miles round Manchester", 1795, Vol. II, p. 436.

[2] Sleigh, J., "History of Leek", 1883, second edition, p. 5.

[3] The map is based on the list of churches compiled by J. S. Burn, who was Secretary of H.M. Commission for collecting the non-parochial registers of baptisms, marriages, and burials. The list is exhaustive so far as available records go, but is not complete, since some congregations died out and left no traces.

[4] Smiles, J., "The Huguenots—their Settlements, Churches, and Industries in England and Wales", 1867.

At the beginning of the eighteenth century silk throwing by power was introduced into England by John Lombe. In 1715 the first silk throwing mill in this country was established at Derby. What considerations dictated the choice of this town ? For the new machinery power was the first essential, hence Spitalfields was out of the question. A site on a stream with a constant supply of water and sufficient flow to provide power was needed. Suitable labour was required, preferably already familiar with handling silk. Both these he found at Derby, where the necessary water power was provided by the river Derwent, and where the hosiery industry, already established, provided not only workers familiar with silk, but also a market on the spot for the thrown silk. The town had, also, communication with London, an asset of vital importance, for London was the port of entry of the raw silk and the chief market of the thrown silk.

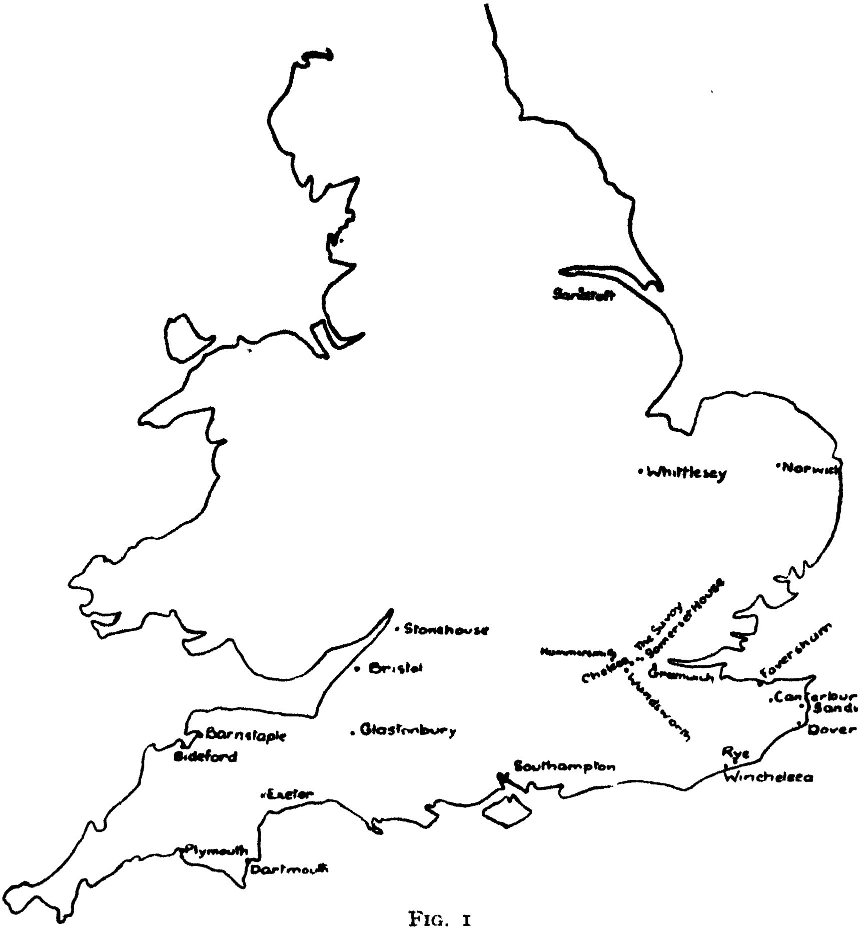

FIG. 1
Sites of Churches founded by French and Walloon Refugees in Sixteenth and Seventeenth Centuries.

So in 1715 the silk industry came to the Pennines with water power its prime consideration. From Derby it spread to the West Pennine towns. In 1732 Mr. Roe commenced to throw silk at Stockport. He obtained a lease for a mill in the park adjoining Logwood Mill and the Corn Mill—"to carry on a design imitable of Sir Thomas Lombe's engines and to fix and to work the same, with power to make a sluice to divert part of the water from the mill sluice to turn a wheel, but not to damage the supply to the waterwheel of the Logwood Mill".[1]

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[1] Heginbotham, H., "Stockport, Ancient and Modern", 1892, Vol. II, p. 318.

Next the silk throwing spread to Congleton, where John Clayton, of Stockport, established a mill in 1752. This, too, was on Lombe's model and water driven.[1] Although Clayton was the throwster the real initiator of the scheme at Congleton was Pattison, a London silk merchant, who wished in this way to obtain his own supplies of thrown silk.

In 1756, Mr. Roe, from Stockport, introduced silk throwing into Macclesfield. Here, too, the machines were on Lombe's model and water driven, and the silk was thrown for London manufacturers. At this time it was customary for Boroughs or Corporations in England to prevent skilled craftsmen from settling within their boundaries unless a high price were paid to the Borough. This was not done in Macclesfield, and so the town was attractive to new industries.

The eighteenth century may be said to mark the firm establishment of silk throwing in the West Pennine region, the mill sites having been chosen where water power was available. Some of the thrown silk was consumed locally by the button men and twisters, but the greater part of it went to the London silk manufacturers. Until the end of the century silk weaving was of small importance in the West Pennine towns, and consisted largely of ribbon weaving for the Coventry merchants.

Broad weaving came to the region in 1790, when Leigh and Voce, in their shop in Back Street, Macclesfield, began the manufacture of broad silks, introducing weavers from London and Dublin. Such was their success that by 1815 there were 1,100 weavers in Macclesfield.

Whereas the beginning of the century saw silk throwing in England in its infancy, the end of the century saw not only throwing, but also the other branches of the silk industry established and flourishing. The last quarter of the eighteenth century, and the first decade of the nineteenth, was a period of real prosperity in the silk towns which was reflected in their rapid development at that time.

Towards the end of the eighteenth century there was a northward extension of the silk industry into Lancashire. With the exception of some silk throwsters in Manchester, the Lancashire silk workers were weavers. Middleton and Leigh were the chief centres. Competition with the cotton industry was felt here, and writing of Middleton in 1795, Aikin said, "The weaving of silk was originally more general than at present, but now gives way to the more profitable branches of muslin and nankeen".[2]

After 1810, the silk industry in the West Pennine towns entered upon a very chequered period. Spells of prosperity were followed by spells of depression. In the first half of the century Chartist agitation made itself felt and after 1860 the industry suffered from the removal of the silk duties which had been affording it a measure of protection. The following figures help to indicate the growth in the size of the industry up to 1860—

IMPORTS OF RAW AND WASTE SILK INTO GREAT BRITAIN

1765	352,000 lb.
1812	1,330,106 lb.
1859	9,920,891 lb.

The proportion of thrown silk to raw silk imported decreased very markedly, indicating the development of the throwing branch of the English silk industry. Between 1815 and 1824 the weight of thrown silk imported was 23¾% of the raw; whilst between 1835 and 1844 the weight of thrown silk imported was only 7¾% of the weight of the raw silk imported. The diagram (Fig. 2) showing the imports of raw silk into England from 1857 to 1929 is a clear indication of the much smaller scale on which the industry was carried on in England after 1860.

The influences which enabled the industry to meet, to some extent, the competition with countries with cheaper labour and producing some, at least, of their own raw silk, were a favourable physical basis to the industry, the reputation which the English silk centres, especially Leek and Macclesfield, had gained, a home market and high-quality goods which are better able to bear comparatively high costs of production. The prime necessities for the successful

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[1] The work was carried out by Brindley. His master had the contract for building the machinery but got into difficulties, abandoned the task, and refused to give up the plans. Brindley, remembered chiefly as a canal engineer, undertook the work himself and completed it without the original plans, actually introducing several inventions of his own.

[2] Aikin, J., *op. cit.*, Vol. II, p. 245.

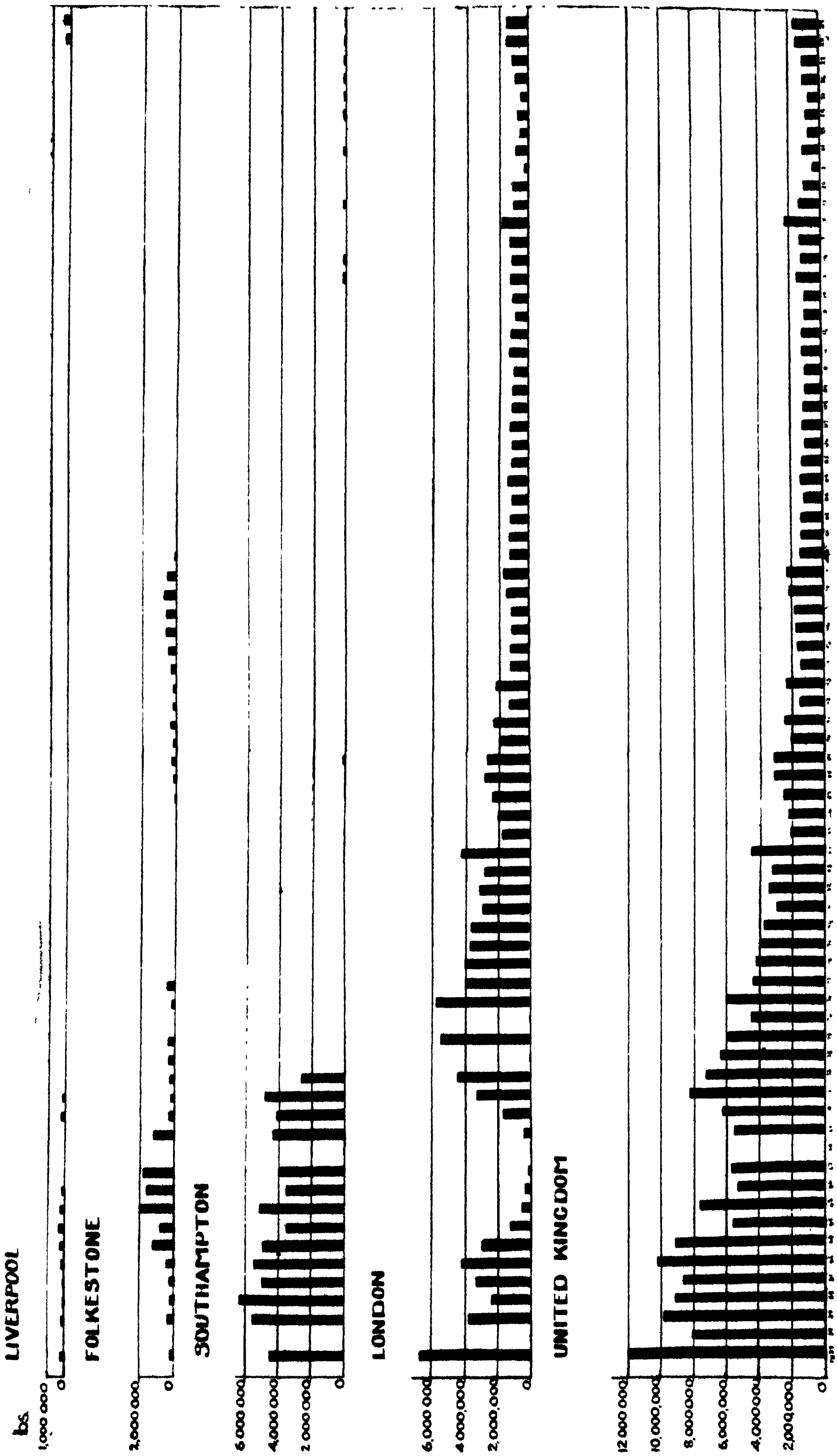

FIG. 2—Imports of Raw and Thrown Silk, 1857–1929.

prosecution of the natural silk industry are accessible supplies of raw material, power, soft water, suitable climatic conditions, available labour, and accessible markets.

The silk worm cannot be reared in England on a commercially profitable scale. Consequently the industry is dependent on imported raw silk. The regions producing raw silk for export to-day are—

World Raw Silk Production

(Tussah Silk included)

SEASONS 1926--1927—1930-1931

	1930-1931‡	1929-1930	1928-1929	1927-1928	1926-1927
Europe	11,067,000	11,243,000	11,287,000	11,034,000	9,215,000
Italy	10,527,000	10,648,000	10,661,000	10,201,000	8,499,000
France	386,000	430,000	452,000	650,000	529,000
Spain	154,000	165,000	174,000	183,000	187,000
Levant	2,822,000	2,601,000	2,513,000	2,293,000	2,359,000
Asia: Total Exp'td*	83,676,000	85,221,000	93,673,000	87,270,000	84,337,000
China, Shanghai†	—	13,755,000	13,194,000	12,313,000	10,825,000
China, Canton ...	18,310,000	6,243,000	6,162,000	5,809,000	7,055,000
Japan	65,256,000	65,036,000	74,075,000	68,839,000	66,193,000
India	110,000	187,000	242,000	309,000	264,000
Total	97,565,000	99,065,000	107,473,000	100,597,000	95,911,000
Tussah	1,500,000	1,060,000	958,000	970,000	1,400,000
Grand Total ...	99,065,000	100,125,000	108,431,000	101,567,000	97,311,000

* The total production of raw silk in Asia is an unknown quantity, therefore export figures have been used.

† Excludes Tussah silk.

‡ Estimated.

The 1930 Japan crop is estimated at 93,957,000 pounds.

(From the Thirth-second Mid-year Report of the Silk Association of America, p. 8.)

During the history of silk manufacture in England, the relative importance of these regions as sources of the supply of raw silk has changed, chiefly as the development of world routes and more efficient means of communication have made the Far East more accessible. Since the industry has always been dependent on imported supplies of raw material, easy access to a port is of great importance to centres engaged in the natural silk industry.

When the manufacture of the raw material requires certain special conditions, conditions of an immobile type, such as climate or water supply, the industry tends to be located in a region where these conditions are coincident. In the absence of any modifying factors, the silk industry will tend to be located where soft waters, climatic conditions, and, in the early days, water power are to be found with easiest access to a port.

Before the development of the silk industry in the West Pennines, London had become the chief silk importing port. Ease of communication with London was then a factor in selecting a site for a silk mill. The first silk throwing mill in England was established at Derby, the first point on the northward journey from London where soft water and water power were to be found. In the West Pennines the town then in best communication with London was the first to receive the silk industry. This was Stockport, for the turnpike from Manchester to London went at first by way of Stockport, Buxton, Matlock, and Derby, and later by Stockport, Buxton, Ashbourne, and Derby. Shortly after the establishment of the silk industry at Stockport, the road via Macclesfield, Leek, Ashbourne, and Derby was turnpiked. The sections of the two routes show how much easier the new route was, so the new route became the more popular and better served. Associated with this is the establishment of the silk industry at Macclesfield, Leek, and Congleton.

The diagram (Fig. 2) shows very clearly the predominant part played by London in importing raw silk. Systematic returns were not made prior to 1857,

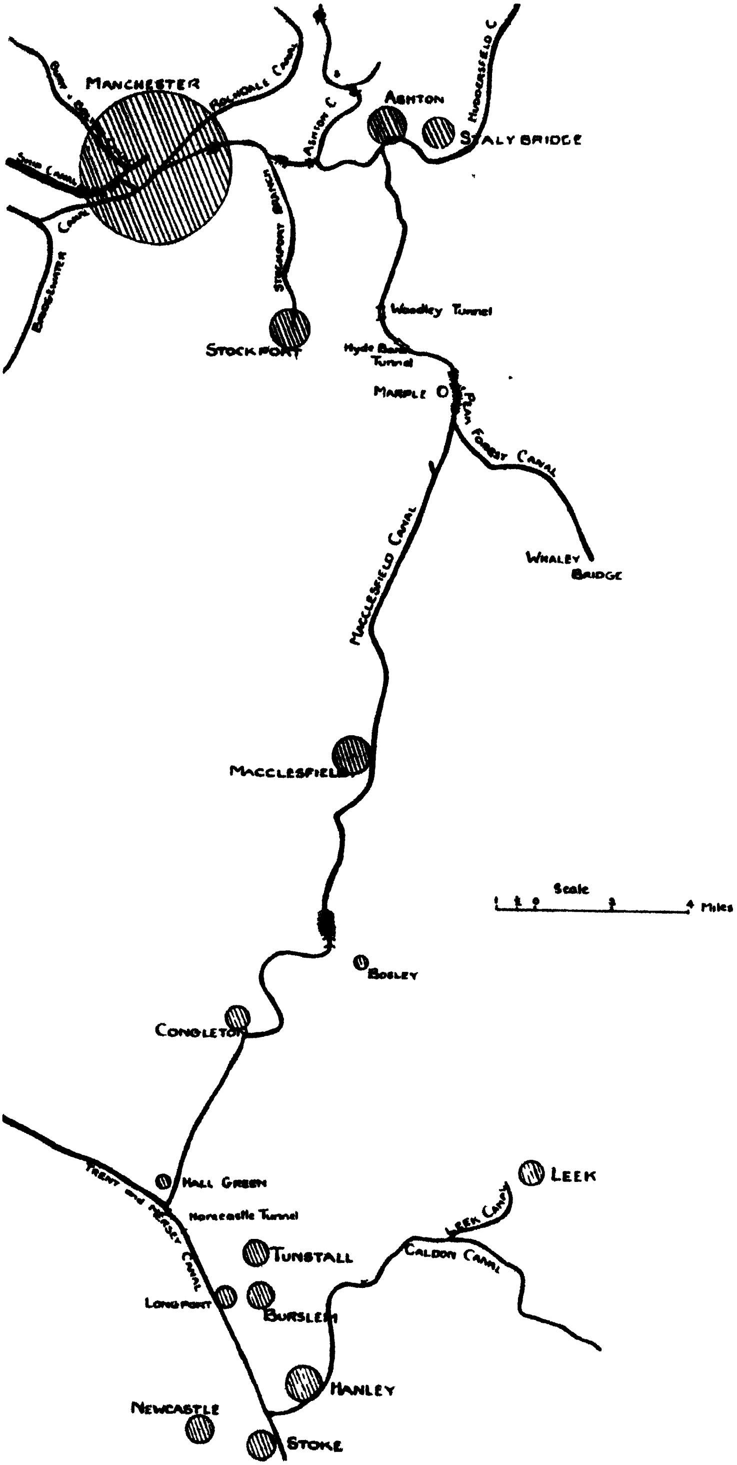

FIG. 3
The Canals of the West Pennine Region.

but such odd references as occur indicate that London had always had the greater part of the silk imports, *e.g.* in 1821, out of a total import of 2,200,032 lb. of raw silk, 2,172,547 lb. were imported at London.

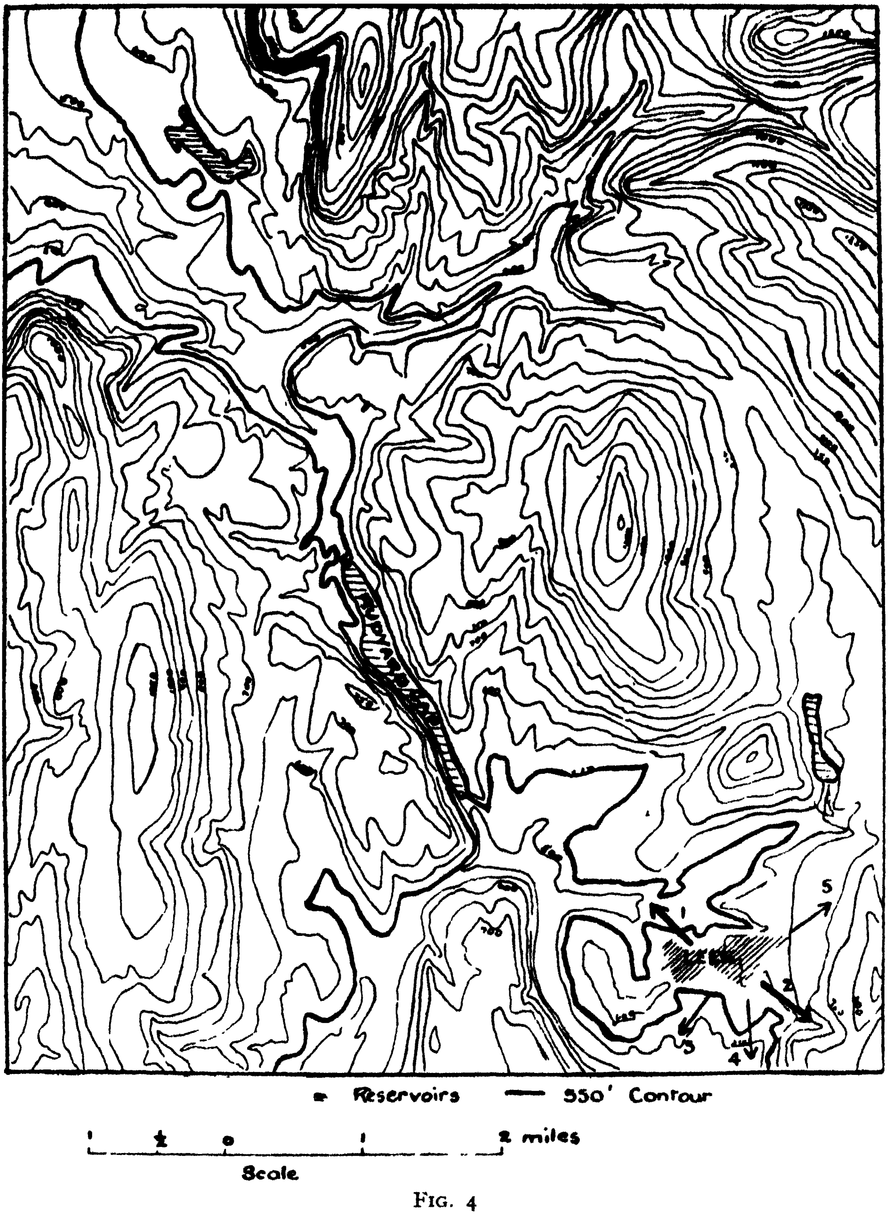

FIG. 4

In the first half of the nineteenth century canal connection with London was of some importance, and there is evidence to show that some silk did journey by canal. Fig. 3 shows that the canal system of the West Pennines was linked with the Trent and Mersey Canal. This was connected by a series of links with the Grand Junction Canal which led to London. This canal system within the West Pennine region, which the topography of the area made practicable, was of much greater importance for the transport of coal. Reference to this is made later in the article.

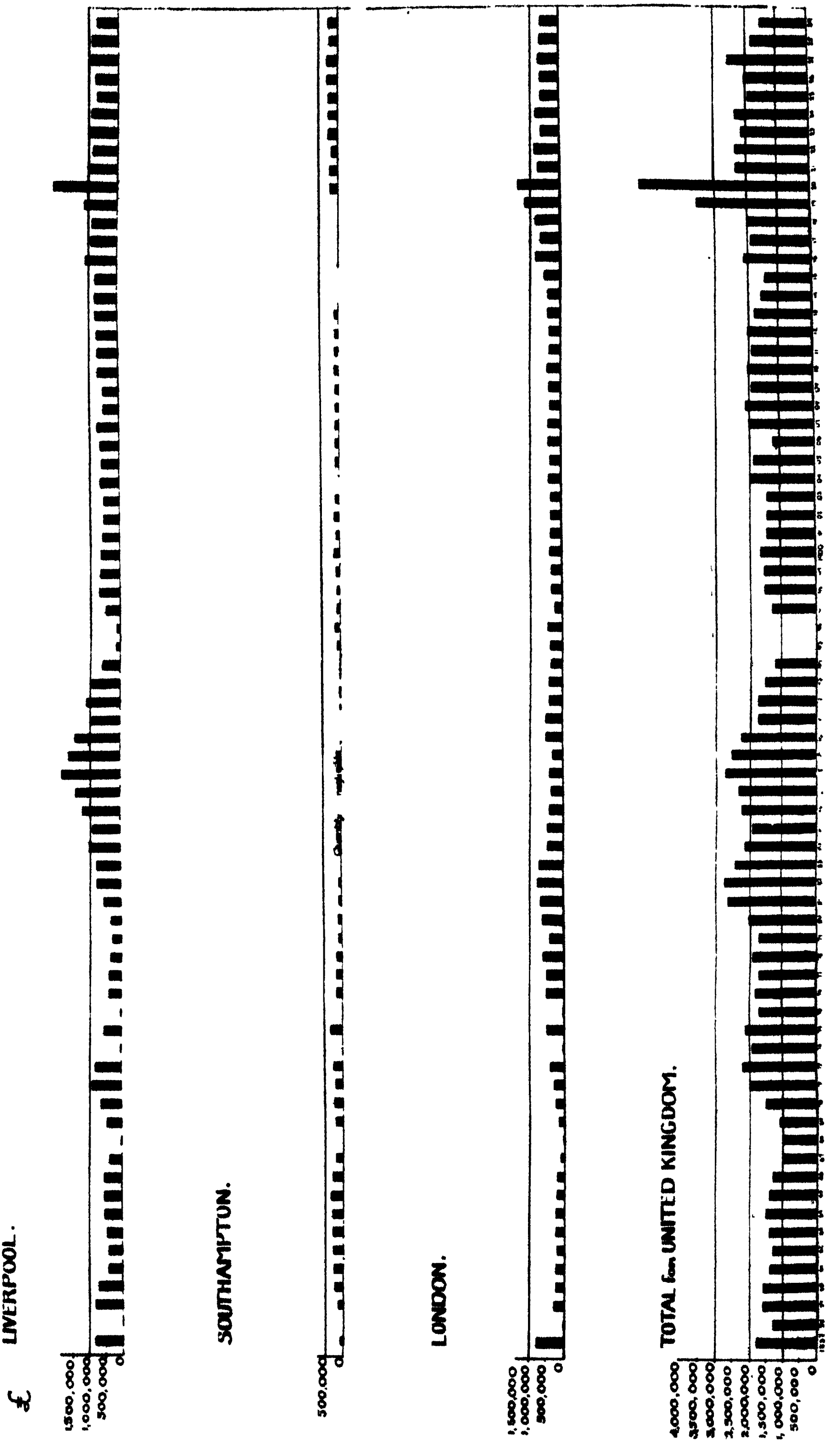

FIG. 5—Export of Silk Manufactures—the Produce of the United Kingdom, 1857–1929.

The middle of the nineteenth century brought the railways. A number of the lines within the region were amalgamated to form the North Staffordshire Railway in 1847. It is by rail to-day that the raw silk comes from London, that the coal comes from Staffordshire, Derbyshire, Yorkshire, and Cheshire, and that the manufactured silk is distributed to the British market and sent to London and Liverpool for export.

Here may be noted that part of the physical history of the region which has been of particular importance to Leek. At one stage in the retreat of the Quaternary Ice Sheet there was formed a series of glacial lakes along the Cheshire uplands between the hills and the ice front. These drained into one another and ultimately through the Congleton anticline at Rudyard at an altitude of approximately 600 ft.[1] Thus was formed the Rudyard Gap shown in Fig. 4, but for which the main road between East Cheshire and London must necessarily have taken a more westerly line and passed through the Midland Gate at Crewe, as the main railway line does.

Whilst London, owing to an early start, continued to take the major share of silk imports, Liverpool, whose development coincided with the growth of the silk industry in the West Pennines, secured an appreciable share of the silk exports, as Fig. 5 shows.

The primary sources of power for use in industry are water and coal. In both of these the West Pennine region is adequately supplied. It has already been shown that in the eighteenth century the availability of water power was an all important consideration in the choice of mill sites. But in the nineteenth century supplies of coal became essential on account of the application of steam power to industry. Transport was then but poorly developed, largely on account of the bad roads. Hence coal supplies, to be of value, must be close at hand. Mining science was then in its infancy and consequently thin seams of coal, near the surface and easily obtainable, were of more value than deeper, thicker seams. Hence the important part played in the early exploitation of the coal measures by shallow pits and outcrop workings.[2] Disused workings scattered along the flanks of the Pennines in this region show whence the early supplies of coal were obtained. The majority of the old pits marked on Fig. 6 are of this type. Of the importance of these early workings to the silk towns there can be little doubt. For example, in 1860, the Poynton Collieries, through canal and railway depots, sold in Macclesfield[3]—

Coal	21,308 tons at the average price of	9/9½ per ton
Slack	28,332 ,, ,, ,,	6/10½ ,,
Total	49,640 tons	

The estimated coal consumption at Macclesfield in 1860 was 80,000 tons. Thus more than half of the town's supply, at that time, came from the Poynton pits. Much of the remainder also came from near-by pits. At least one silk firm had its own coal pits. In the 1825 Directory of Macclesfield it is stated, "coal is obtained from the neighbouring collieries of Adlington, Poynton, Worth, Rainow, Hurdsfield, and also from Staffordshire.[4]

In the course of the processes through which the raw silk passes after arrival in this country, the relative humidity of the atmosphere is the first climatic factor to exert an influence. Apart from any re-reeling which may be necessary, the silk first passes through the process of throwing, during which the silk threads are twisted. The influence of humidity in the process has been shown by Mr. C. F. Goldthwait by experiments, the results of which were published in the Rayon Year Book 1928–1929.[5] By his experiments he showed the need for uniform humidity during throwing. Adequate humidity is also necessary to minimise the generation of static electricity, which occurs readily through the friction between silk threads and glass, in the course of throwing. In weaving, too, the relative humidity is an important consideration. Manufacturers find that humidities of 65% to 75% with an air temperature of 65° F., give the best working conditions.

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[1] Ogden H. W., "Cheshire Villages", *Journal of Manchester Geographical Society*, Vol. 39, p. 128.

[2] For detailed account of the geology of the region see "Geological Survey Memoir—Geology of the Country round Stockport, Macclesfield, Congleton, and Leek", 1866.

[3] Information supplied by Mr. G. H. Greenwell, of Poynton Collieries.

[4] Varey's "Directory of Macclesfield", 1825, p. 13.

[5] Goldthwait, C. F., "Silk, Rayon, and Humidity", *Rayon Year Book*, 1928–1929, p. 152–153.

Fig. 7 shows the average monthly humidities taken from the daily 9.0 a.m. readings over a period of seven years for Leek and Macclesfield. These are the readings for the outdoor conditions which are much cooler than those inside the mill. Such outdoor humidities as the graphs show give the optimum atmospheric humidities for silk manufacture at the indoor temperatures of 60° F. to 65° F. The graphs show, too, the uniformity of atmospheric humidity throughout the year. It is only for odd days or, at the worst, for short spells of a few days at a time that low relative humidities cause the silk worker trouble with his silk.

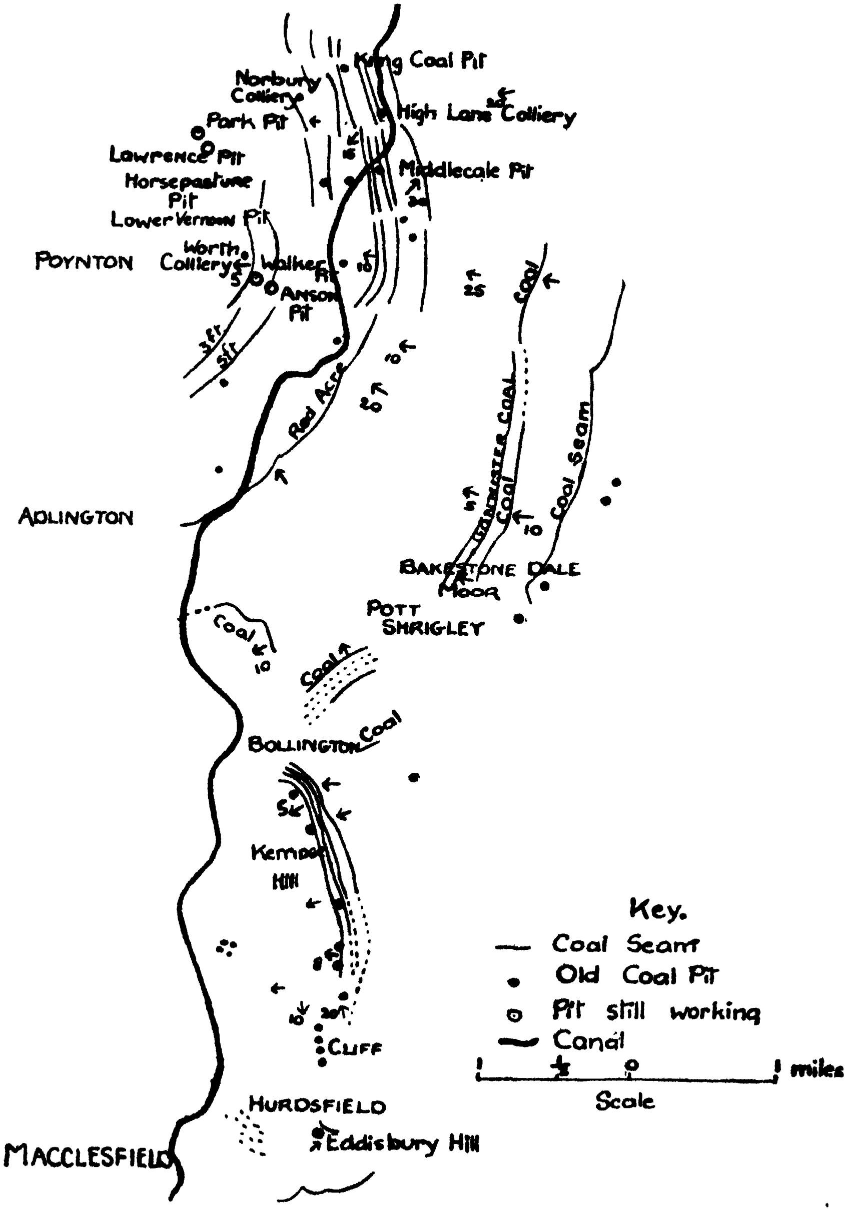

FIG. 6
Coal Seams and Old Coal Pits around Manchester.

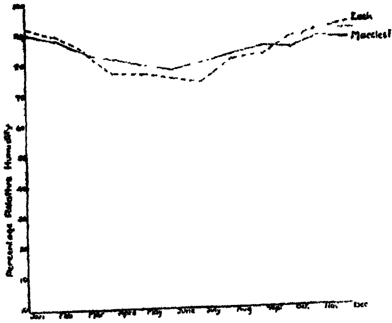

FIG. 7
Humidity Curves.

These spells are usually associated with winds from an easterly direction. Fig. 8A and 8B show firstly that these winds bring little or no moisture, and, secondly, that at Leek and Macclesfield these winds from an easterly direction occur comparatively infrequently. In each case the diagram is based on daily observations over a period of seven years.

Rainfall is the other climatic factor of importance. The flanks of the Pennines whose streams serve the silk towns form a belt in which there is an average annual rainfall of more than 40 in. The rainfall graphs (Figs. 9A and 9B) show

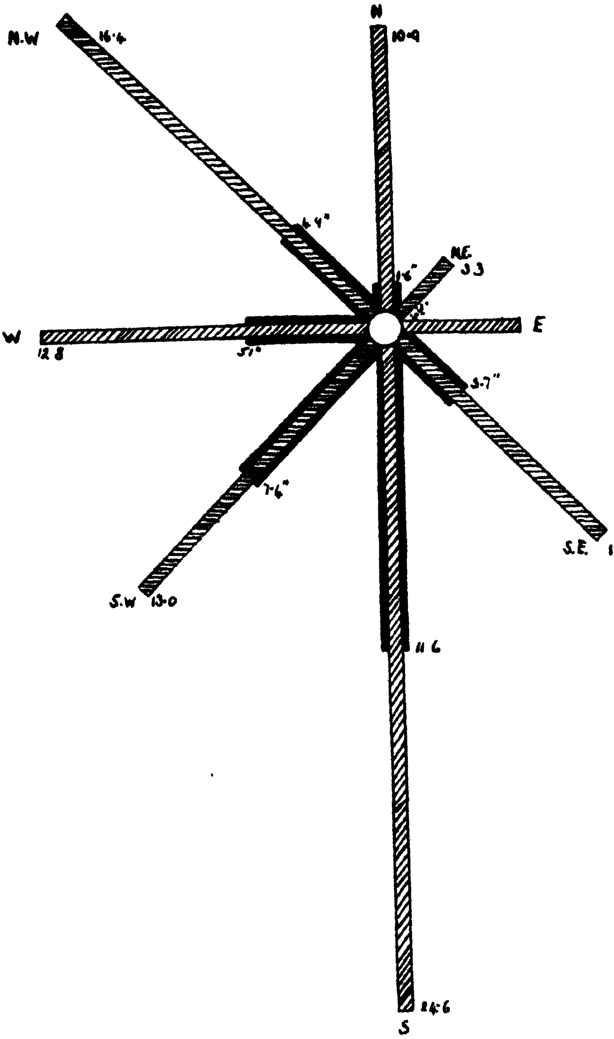

FIG. 8A
Macclesfield Rainfall and Wind Directions. Rainfall in inches shown in black for each wind direction. Wind percentage frequency shown by shading.

that there is no period of drought, a particularly important feature in the days when mills depended on the streams for power. The Millstone Grit, which is the predominant rock formation in the catchment basins of the Bollin, the Churnet, and the Dane, gives a high percentage "run off". In addition much of the surface cover of the catchment basin is moorland or poor pasture, which absorb a minimum of moisture. Thus a large proportion of the rain that falls drains to the streams. Amount and intensity of the rainfall, together with surface slope and permeability of the soil, have an important effect on the quality of the water.[1] Other things being equal, least mineral matter is found in regions of highest and most evenly distributed rainfall.

The character of the water supply has been one of the most effective of the geographical factors favouring the silk industry in the West Pennine towns. The change in rock structure from the Carboniferous Rocks which form the Pennines to the Triassic Rocks, overlaid by sands, gravels, and clays of Pleistocene Age, which form the Cheshire Plain, is reflected in the character of the water in the streams draining the formations. The water from the Millstone Grit of the Carboniferous series is soft, whilst that from the Triassic Rocks is hard. It is significant that the sites of the silk towns are such that their streams are still drawing water from the Millstone Grit.

To be suitable for use in the silk industry, water must have the following properties[2]—freedom from suspended matter; low degree of hardness; freedom from excessive iron; absence of strong acids and alkalies; and absence of excessive amounts of colour and organic matter.

The following table gives details of the character of the water supply in the West Pennine silk towns and, by way of contrast, in Spitalfields. It will be

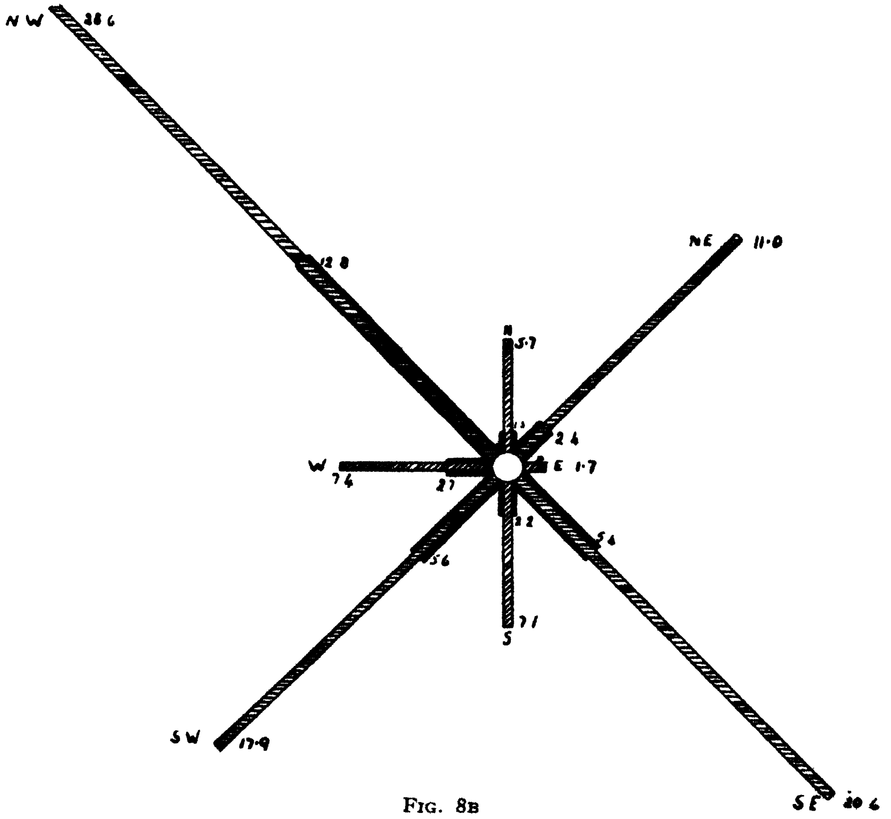

FIG. 8B

Leek Rainfall and Wind Directions. Rainfall in inches shown in black for each wind direction. Wind percentage frequency shown by shading.

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[1] For details see A. Rogers, *Industrial Chemistry*, London, 1925, p. 43.

[2] Cook, A. A., "Raw Silk Soaking", *Textile Mercury*, 8th November, 1929.

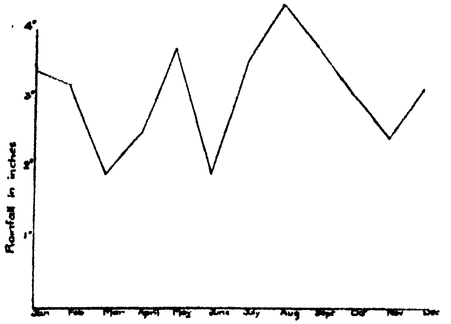

FIG. 9A
Macclesfield Rainfall Monthly Averages.

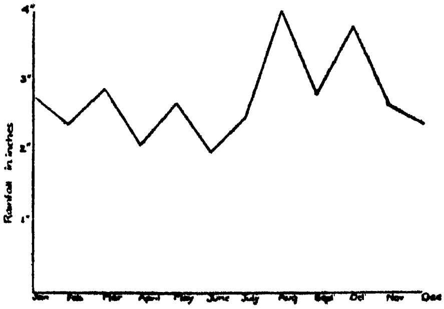

FIG. 9B
Leek Rainfall Monthly Averages.

seen that in Congleton the water from the Dane is best suited to silk manufacture, but as in the early days the Dane was used for power, the number of mill sites on the river was limited. The mills situated in the town and away from the river had to use town's water, which is not so suitable for delicate processes. This is a partial explanation of the small development of the silk industry in Congleton compared with Leek and Macclesfield. The analyses leave no doubt as to the high degree of suitability for the silk industry of the water supply in Macclesfield and Leek.

Analyses of Water Supply[1]

	Macclesfield	Leek	Congleton T.	Congleton Dane	Spitalfields
			Parts per 100,000		
Total solids dried at 120°C.	9·00	10·0	35·4	14·4	—
Combined chlorine ...	1·3	1·0	2·1	1·3	2·4
Equivalent NaCl	2·15	—	—	—	—
Nitric nitrogen	·04	·08	·18	·12	·24
Ammoniacal nitrogen ...	—	—	—	·032	·0012
Nitrous nitrogen	—	—	—	—	—
Albuminoid nitrogen ...	·0022	·003	·004	·016	·0017
Oxygen absorbed in 4 hours at 27° C. ...	·032	·036	·008	·14	·09
Lead or copper	—	—	—	—	—
Temporary hardness ...	3·3	6·0	14·5	6·2	17·9
Permanent hardness ...	3·8	4·57	12·0	4·8	7·5
Total hardness	7·1	10·57	26·5	11·0	25·4

Whilst the main agents in bringing the silk industry to England were political events on the Continent of Europe, the main factors in bringing the silk industry into the West Pennine region were geographical. The first geographical attractions the region offered were water power and soft water. Next was the comparative ease of the Manchester, Macclesfield, Rudyard Gap, Leek, and Ashbourne route to Derby and London. Then with the development of steam power and its application to industry, the region afforded easily obtained supplies of coal and again suitable soft water for steam raising. With the exhaustion of local supplies of coal, the region was advantageously situated to obtain coal from three great mining regions. With the further development of roads and railways, the region was not only well linked with the raw silk importing port of London, but with the manufactured silk exporting port of Liverpool. The region has also a central position for the distribution of the products of the industry to the British market. Lastly, throughout the region, there is high atmospheric humidity well suited to the needs of silk manufacture and contributing to the success of an industry which other factors had attracted.

C.L.M.

For a more complete treatment of the subject by the same author see "*The Geographical Basis of the Natural Silk Industry of the West Pennines—thesis approved for the degree of M.A. at London University.*" Full acknowledgments, which considerations of space forbid in the foregoing article, are made in the thesis itself which is deposited in the Library of the University of London.

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[1] Analyses kindly supplied by the water engineers of the towns mentioned.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXV NOVEMBER 1934 No. 11

PROCEEDINGS

London Section

Meeting at the Clothworkers' Hall, Mincing Lane, E.C., on Tuesday, 14th March 1933. Lecture on "Ceremonial Fabrics", by G. A. Rushton, A.T.I. Chairman: Mr. John Howard, F.T.I.

CEREMONIAL FABRICS*

In view of the wide scope of the subject, the Lecturer said he proposed to deal with fabrics used in the ceremonies of (I) The State, (II) The Church, (III) The Services, Army and Navy, although much might be added about the ceremonial garments and uniforms worn by the Orders, such as the Freemasons, the City Livery Companies, and so forth.

The State

Ceremonial vestments are not common to everyday life, and therefore it is of interest to consider their form and in some cases their origin. The most characteristic is no doubt the Robe. Planché† gives a lengthy discourse on the subject of robes, and says that in French, robe is the general term for a gown, but is limited in English to State and official garments—the Coronation and Parliamentary robes of the Sovereign, of Peers and Peeresses, Judges, etc.

At one time, and in the time of the early Kings of England, the vestments do not appear to have differed from their ordinary apparel, except that they may have been made of more costly material, and simply consisted of a long tunic and a mantle, the latter in the thirteenth century being lined with ermine and occasionally having a cape of ermine covering the shoulders.

No particular colour was assigned to the Coronation mantle, but we hear of kings on certain days sitting at dinner in their scarlet robes, which suggests some distinction, by which might be meant their Parliamentary robes.

The official records of the Coronation of Queen Mary in the College of Arms, show that Mary Tudor, daughter of Henry VIII, proceeded from Westminster Hall to the Abbey for the coronation in her Parliamentary robes of crimson velvet, consisting of a mantle with a train, a surcoat with a kirtle furred with miniver, a riband of Venice gold, the mantle of crimson velvet powdered with a lace of silk and gold and buttons and tassels of the same.

The wardrobe account of the robes of Queen Elizabeth is described as follows—*Item:* One mantle of crimson vellat (velvet) furred throughout with armoynes (ermines), the mantle lace of silk and gold with buttons and tassels to the same. *Item:* One kirtle and surcoat of the same crimson vellat, the train and skirts

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[*] The delay in publication of this paper has been largely due to the extra work carried out by the author at the request of the Publications Committee, and thanks are due to all concerned for their kind assistance therein.—EDITOR.

[†] J. R. Planché. "A Cyclopædia of Costume" (1876).

furred with armoynes, the rest lined with sarconest (sarcenet)*. After the ceremony, it would appear that she changed her apparel for the banquet in Westminster Hall, her robes being those of "estate" and consisting of a rich mantle and surcoat of purple velvet furred with ermine.

Since the sixteenth century the King's robes of State have consisted of the following—

(*a*) The Parliamentary robes, which the King puts on in the Palace of Westminster before he proceeds to the Abbey, consisting of a surcoat and mantle of crimson velvet furred with ermine and bordered with rich gold lace.

(*b*) The Coronation robes, *viz.* the Colobium Sindonis (the Colobium is an ancient ecclesiastical vestment reaching to the ankles and having either no sleeves or short ones to the elbow only) of fine white cambric or lawn (probably of linen), usually trimmed about the neck, arm-holes, and round the bottom with the finest point lace.

(*c*) The Dalmatic, or super tunic, or surcoat, of rich cloth-of-gold, lined with crimson taffeta with a belt of the same stuff lined with white tabby and furnished with a gold buckle, runner, and tab to which hangers are affixed for the sword.

(*d*) The Stole of cloth of tissue, lined with crimson sarcenet, about an ell in length and three inches wide, and, finally,

(*e*) The Pallium or mantle of cloth-of-gold brocaded and furred with ermine.

The robes of "estate" in which the Sovereign returns to Westminster Hall to the banquet are of purple velvet furred with ermine. Several of these vestments will now be described in more detail.

The Dalmatic is a long robe or super-tunic partly open at the sides and so named from its being of Dalmatian origin. It is an ecclesiastical vestment and also a portion of the Coronation robes of Sovereign and Princes. The colour appears to have been arbitrary, for we find them of purple, crimson, blue, and gold tissue, and covered with costly embroidery.

It was the ancient custom of the Pope to confer the use of the Dalmatic as a privilege on Bishops, who granted it in their turn to their Deacons. Adrian I, 772–795 A.D., for example, presented many Dalmatics to different churches and Bishops.

The Dalmatic† is mentioned early amongst the Kings of England. Richard I and King John both wore Dalmatics, that of King John being of a dark purple colour. Walsingham, in his account of the Coronation of Richard II, says the King was first invested with the tunic of St. Edward and then with the Dalmatic. Being worn over the tunic, it is frequently called a super-tunic and also a tunic simply, as in point it was. Henry VI is said to have been attired at his Coronation "as a Bishop that should sing Mass with a Dalmatic like a tunic and a stole about his neck".

The Stole is an embroidered band or scarf forming a portion of the ecclesiastical vestments of a priest, and also the Coronation robes of a Sovereign Prince.

When the tomb of Edward I was opened in Westminster Abbey, 1774 A.D., the body was discovered to be arrayed in a Dalmatic or tunic of red silk damask and a mantle of crimson satin. A stole was crossed over his breast of rich white tissue studded with gilt quartrefoils in filigree work and embroidered with pearls in the shape of true lovers' knots.

The regal stole, from some inexplicable circumstance, was given, as early as the reign of Henry VII, the name of Armil and is often referred to under this name.

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* Sarcenet, a species of fine, thin silk fabric, soft, plain, or twilled, was the old Saracen cloth, originally introduced into England in the thirteenth century, and very popular as a dress material in the eighteenth century.

† The Dalmatic was originally of white linen but since the tenth century it has usually been made of fine wool or silk.

The Pallium* or Imperial Mantle is one of the most important ceremonial vestments of the Sovereign. It was the principal outer garment of the ancient Greeks, whilst among the Romans it signified a cloak. In the eighth century the name was applied to a long band of white linen, about three inches broad, worn as an ecclesiastical vestment by the Pope.

Custom immemorial has ordained that the British Coronation Pallium should be of cloth-of-gold. An account of the fabric worn at the Coronation of King Edward VII is given in Sir Frank Warner's book *The Silk Industry*. Messrs. Warner, of Braintree, were entrusted with the task of producing the most perfect ground possible in plain cloth-of-gold. The required surface was difficult to obtain, but after patient experiment, the problem was solved by using for the weft a twist composed of one round and two flat strands of very fine gold thread. The gold was the purest that could possibly be used and contained even less alloy than the standard gold coinage. For the ground weft the finest gold-coloured silk was used and both interwoven with a rich silk warp. Fig. 1 shows the Coronation robes of King Edward VII and Queen Alexandra, and their Majesties the present King and Queen, as now exhibited in the London Museum.

Through the kindness of Messrs. Warner, a piece of the actual fabric was shown at the lecture. Upon this magnificent fabric was embroidered the Rose, Thistle, Shamrock, and Eagle, as well as the Lotus for India, which was employed emblematically for the first time upon the robe of a monarch who was Kaiser-i-Hind as well as King of England. This work was entrusted to the ladies of the Royal School of Needlework.

At the Coronation of our present King, His Majesty decided to use, not the pallium of King Edward, but the magnificent specimen of Spitalfields weaving, which was prepared for King George IV. After more than ninety years the soft and supple cloth-of-gold of this old vestment came out as brilliant and untarnished as when first worn. Brocaded into this vestment in exquisite colouring were the Rose, Thistle, Shamrock, and Eagle of Sovereignty—a truly magnificent specimen of English weavers' craft. The pallium of Queen Victoria was also of brocaded cloth-of-gold, of Spitalfields make.

The super-tunic, worn under the pallium at King George V's Coronation, had to be made afresh, and the cloth-of-gold had to match precisely the ground of the pallium. Also, as it is the hereditary right of the Girdlers Company to present the belt to which his sword is girt and the armil or stole, enough cloth-of-gold had to be prepared for these purposes.

The Stole† (Fig. 2), which was made and embroidered by Messrs. Hobson and Sons, is of special interest, as all the emblems of the daughter nations were for the first time introduced into ceremonial use on such an occasion. In addition to the Rose, Shamrock, Thistle, and Red Dragon and Eagle of Sovereignty, there was embroidered the Lotus for India, the Maple for Canada, the Southern Cross for Australia, the Four Stars for New Zealand, and the Mimosa for South Africa, thus constituting a new precedent of great historical interest. The embroideries were done with gold tambour, and the purest silk obtainable. The crowns, although small, and the rose, shamrock, thistle, etc. are "proper", that is, correctly done in accordance with the rules of heraldry.

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* In early times the word was applied by the Romans to the Greek cloak particularly used by Diogenes and his followers. Later it became, in an enriched form, the robe of an Emperor.

†A. W. Pugin, in his "Glossary of Ecclesiastical Ornament and Costume", describes a stole as—"A narrow band of silk or stuff, sometimes enriched with embroidery and even jewels, worn on the left shoulder of deacons and round the necks of bishops and priests, pendant on each side to the ground. Stole in the original acception of the word signified a robe. The stole among the Romans was the ordinary dress of women as the toga was that of men. It was a vest covering the whole person except the head, being a tunic with sleeves reaching to the feet, of a purple colour adorned with gold bands, falling in many folds, *and there can scarcely remain a doubt of the fact that in its present form, it is but the border of the vestment so called.*"

The long velvet mantle, borne by eight pages, was made of English velvet trimmed with gold lace. A piece of the velvet which was used for peers' and peeresses' robes at the Coronation of King Edward was also kindly lent by Messrs. Warner. This is typical of the richness of such a fabric. It is hand woven and cut, all silk, both warp and weft, and has a rich silk pile produced by using 56 wires to the inch. So close is the pile that an expert weaver would not produce more than one yard in a working day.

The Queen's dress and train were also of much significance, as Her Majesty had them designed in view of their importance and symbolism, not only in Westminster Abbey, but also for the imperial and splendid scene at Dehli, when she would appear beside the King in full Durbar. The ground of the dress was white satin of the most sumptuous character it was possible to weave. The workers of Princess Louise's School in Sloane Street, Chelsea, worked the beautiful scheme which showed the English Rose and the cable that links other lands to it, whilst in a prominent place was the Star of India and the Lotus, more appropriately employed, as it is not only the sacred flower of the country, but in some of the older mythologies of the East is associated with the sovereignty of the waters. The train was of rich purple velvet, supplied by Messrs. Warners, and upon it was embroidered the symbolic devices and the letter "M" surmounted by the Crown.

Other fabrics exhibited at the lecture included a sample of that used in the Queen's wedding dress. The ground was white satin, thick and rich, yet soft and susceptible of taking graceful folds. The design introduced the Tudor rose in the form heraldically adopted after the union of the rivals of York and Lancaster, and with it clusters of may, symbolic of the name by which the Royal bride was affectionately known. Linking these were silver ribbons brocaded into the fabric and tied with true lovers' knots.

In addition, a beautiful velvet fabric was shown from the same piece as that from which the Coronation chair is upholstered. This is of three-coloured figured velvet with a portion of terry or uncut pile. The design is produced on a red silk satin ground and is obtained by using two distinct pile warps, one dark green, almost black, and the other fawn. Round the outline of the design, terry weaving is often introduced to give a semi-tone effect. The pile is obtained by the use of wires in the usual way, but a separate set is required for the terry or uncut pile.

[A lantern slide of this fabric in the loom was exhibited. It illustrated the method of weaving, showing clearly the pile ends on bobbins to allow for the extra take-up, the satin ground warp being on a beam.]

Golden Fabrics.

Frequent reference to "cloth-of-gold" prompted the Lecturer to quote the following historical details from *A Short Account of Ancient Textile Fabrics*, printed at Hitchin, 1893—

"Of the several raw materials which from the earliest periods have been employed in weaving, though not with such frequency as silk, one is cloth-of-gold, which, when judiciously employed, adds not a barbaric but an artistic richness.

"The use of gold for weaving existed almost certainly among the Egyptians long before the days of Moses. The psalmist, describing the dress of the king's daughter (that is Pharaoh's daughter), not only speaks of her being 'in raiment of needlework', but that 'her clothing is of wrought gold'. In order to be woven, the precious metal was at first wrought in a flattened, never a round or wire shape. To this day the Chinese and the people of India work the gold into their stuffs after this ancient form.

"From the East this love of gold cloth reached the southern end of Italy, and thence soon got to Rome. Pliny, speaking of this textile, says, 'gold may be spun or woven like wool, without any wool being mixed in it'. How far this is technically correct it is difficult to say. (Specimens of gold fabric examined by the Lecturer have all had a silk or cotton warp, the gold being used as weft only, along with another silk weft or alone.)

"Our own country can furnish examples of this golden textile. On Chessel Down, in the Isle of Wight, an Anglo-Saxon place of burial brought to light some pieces of gold strip, thin and quite flat. Another very remarkable piece, probably a fragment of a stole, was found at Durham in the grave of Bishop Pudsey, who was buried about the middle of the twelfth century. It is made of rich silk with a diaper pattern in gold thread.

"In the old English ritual, plain cloth-of-gold was allowed to be used for white. Thus, in the reign of Richard II, among the vestments at the Chapel of St. George, Windsor Castle, there was 'one good vestment of cloth-of-gold', and St. Paul's, London, had at the end of the thirteenth century two amices* embroidered with pure gold. As time went on cloths-of-gold had other names. What in the thirteenth century was called, first, ciclatoun, then baudekin, and afterwards nak, was called two hundred years later tissue, a bright shimmering golden textile. The very thin smooth paper which still goes under the name of tissue paper, was originally made to be put between the folds of this rich stuff to prevent fraying or tarnishing when laid by."

The Church

In addition to the ecclesiastical vestments used in connection with the Coronation robes, the Lecturer mentioned in more detail some other vestments that appear to be confined to Church use only.

The Chasuble, Chasible, or Chesable, is the upper or last garment put on by the priest before celebrating Mass. Originally it was a vestment worn by laymen as well as ecclesiastics, and common to various orders of churchmen. The primitive chasuble was perfectly round with an aperture in the centre for the head. In this form it covered the whole body and the very name is said to be derived from *casula*—a small house. Chasubles were made of velvet and richly decorated with embroidery and even jewels at a very early period. Orphreys have also frequently been used as decorations from early times, these being gold-embroidered bands that come down in a Y-shape from the shoulders, back and front. At the present time materials such as deep cream silk damask, with applied orphreys of gold brocatelle are used. (See Fig. 3.)

The Cope (Fig. 4) is a vestment like a cloak worn in solemn processions, originally to serve as a protection from cold or rain. They were early ornamented with embroidery and jewels, and in the thirteenth century became the most costly and magnificent of all ecclesiastical vestments. In shape they now form an exact semi-circle when spread out, and when worn fall in graceful folds. The garment is fastened across the chest by a clasp called a morse.

Altar cloth is a term that may be indifferently applied to the linen coverings of the altar, and to the embroidered hangings that are suspended over the back or front. Every altar is now required to be covered with three linen cloths. The first is embroidered, the second, which is the largest, has five crosses representing the five wounds of Christ, and the third, the "corporal", was originally three-quarters of a yard square and embroidered with one cross. Formerly this linen was always made on the Continent, but now Belfast produces a good quality. Altar frontals probably originated from the custom of placing shrines of Saints beneath the altars which were protected from dust by these hangings. The hangings were suspended from rods that were concealed by a fringed bordering hung down before them, and this narrow lappet is still found on many frontals.

Fabrics used in the Church appear to have always been rich and sumptuous. Whether for altar frontals, dossals, chancel hangings or vestments, silk has always played a prominent part, as well as gold and silver threads, either embroidered or woven into the fabric into some of the most beautiful of designs.

* The amice (Latin *amicire* = to throw around) was an oblong piece of linen worn by the celebrant at Mass.

A few typical examples of these rich fabrics, all of which were prepared and kindly lent by Messrs. Warner & Sons, were shown at the lecture.

(1) A rich white silk damask of English design (Fig. 5), used for a number of purposes in the Church—that is for both decoration and for vestments, either alone or as a base for embroidery. In all these designs, not geometrical, the jacquard principle of weaving is essential.

(2) A sample of cream satin, used in the Church for vestments. Satin was not unknown in England in the Middle Ages. When it first appeared on the shores of the Mediterranean it was called aceytuni, a term which slipped through Italian lips to zetani, and coming westward seems to have dropped its letter "i" and became satin.

(3) A metal brocade, reproduced from an Italian fifteenth century design with a rich silk warp, and a silk weft to form the satin ground of the fabric. Gold and silver metal threads are introduced to form the design. This fabric is generally used for altar frontals, but a well-known Bishop has a cope made from this particular fabric. It is rich and very heavy, and a vestment made from it must weigh heavily upon the shoulders.

(4) Another metal brocade (Fig. 6), depicting birds, crowns, and circular panels, emblematic of the type of design prevailing in Italy about the fourteenth century, and still in use at the present day. The term brocade was originally confined to embroidery upon a fabric of silk, the word being derived from a Latin word *brocare*, to prick or stitch. Italy was first famed for its brocades, and later our own country became famous, for English brocades or embroidery were greatly appreciated abroad. According to the Issue Rolls, Henry III had a chasuble of English brocade, whilst Edward II paid a hundred marks for a choir cope which was to be sent to the Pope as an offering from the Queen. Nowadays brocade is a woven textile.

Design in fabrics for the Church has changed less than in any other form of decoration. Reproductions of silk fabrics of the thirteenth–seventeenth centuries are still in use, but during the present century many designs of purely English origin have appeared, such as that shown in Fig. 5, which has a not too obvious "right" and "wrong" way up. Qualities vary considerably from mercerised cotton of 100 threads per inch to the finest silk with 450 threads.

The Services

The Army—Uniforms are the repository of the fashions of bygone ages and many interesting facts emerge when they are considered. There is scarcely a button, a tab, a facing, or a piece of braid that is not a vestige of the clothes worn in some earlier days. The more special or ceremonial the occasion, the more ancient the costume worn for the occasion. The Yeomen of the Guard has still the almost unaltered dress of 1485. Uniforms in the Army date back to Cromwell. At the beginning of the Civil War the soldiers of both armies were dressed in whatever colour their colonels chose to select. Every colour was visible on the backs of both Parliament and Royalist forces. At Edgehill, both sides were simply distinguished by scarves, but gradually greater uniformity became the rule amongst the Parliamentarians. At the relief of Newark, in 1644, we hear of Norfolk redcoats. Again, a newspaper published in 1645, says, "The men Redcoats all . . . , the whole Army only are distinguished by several facings on their coats". As Fairfax's own colours were blue, his regiment had blue facings and possibly in this way the regiments got their different facings, taking the previous colours of their colonel.

The troops Cromwell sent to Flanders in 1657 were equipped with new red coats, and in the literature of the Commonwealth "redcoat" and "soldier" are used as synonymous terms. Soldiers were known as red coats in Wellington's Army and in South Africa in the first Boer War about 1881. Wellington apparently did not worry his officers or men about details of uniform on active service. Grattan, of the 88th, says—"During the Peninsula War, provided we brought our men into the field well appointed with sixty rounds of ammunition each, he never looked to see whether trousers were black, blue or grey, and as to ourselves we might be rigged out in any colour of the rainbow if we fancied it." The uniform of the infantryman of the time appears to have been a red coat and white trousers, the light dragoon a blue coat with white buckskin trousers, the field artillery blue coats, and the rifle battalion dark green tunics and trousers.

Blue-grey trousers and half boots were adopted in place of breeches and gaiters in 1823, and in 1830 for all ranks it was directed that white linen trousers were to be the wear during the summer months and grey cloth in the winter. Although in the 80's some attempt had been made to differentiate between the dress worn in peace and war, it was the South African War which changed the whole outlook in army uniforms. Formerly, one of the chief objects was to be conspicuous and distinct, so that friend and foe could easily be distinguished even at a distance, but then a protective colouring was essential in war—hence khaki.

An interesting story is told of the special blue-grey cloth introduced in 1904 for the Guards' greatcoat. After the pattern was sealed it was found impossible to get the exact shade or supplies near enough to satisfy the inspector. Even the makers of the pattern could not get it. When pressed for a reason, they explained that, when they were dyeing the wool for this pattern piece, there was a very high wind, which so shook the chimney that a great quantity of soot fell into the dye vessel, and although it was rapidly skimmed off it altered the shade a little and gave a smokiness to the blue-grey mixture which they could not afterwards reproduce. A somewhat similar material called the Atholl Grey is used as great-coats for generals and field marshals. This fabric is said to be actually smoked to get the desired effect.

For that portion of the Army which plays a part in ceremonial, such as the Household Cavalry and Foot Guards, with their respective Bands, the cloths have been standardised. The scarlet cloths* are numbered 1 to 4, and the blue cloths 1 to 7. The number 1 in both cases is the best quality, is face-finished and used for the staff. All the scarlets are cochineal-dyed in the piece. The blue cloths are all wool dyed with vat indigo. Both the blue and scarlet cloths are plain woven and are milled in finishing from about 90 inches in the loom to 56 inches finished width. The particulars of weight, ends and picks, strengths, etc. are fairly well known in the trade, or can be readily procured. Samples of most of the cloths were shown. Special mention might be made of the State clothing of the drum major of the Foot Guards as an example of a special and expensively dressed personage. His coat is made of cloth (crimson No. 1), profusely adorned with special gold lace and embroidery. He wears short trousers of tartan blue (No. 2), gaiters of a white cloth, a blue velvet cap, a sash of crimson silk with gold fringe, and is also provided with a cloak of cloth (crimson No. 1) with a gold lace collar.

King's and regimental colours are works of art and require very highly-skilled workmanship (see Fig. 7). The ground of the colour must be of the best silk procurable, usually "lutestring" or "grosgrain". All the lettering is done with gold thread and the wreaths, both union and laurel, in best quality embroidery silks. A notable feature is that both sides are alike, *the embroidery*, with the exception of battle honours and name of regiment, being done through the fabric. (The battle honours, etc. have to be done separately for both sides and appliqué, or they would read in reverse on the back of the colour.)

The Navy—Although the Navy is such an old service, uniforms for the men only date a little before the year 1767. Crews of the galleys, the boats reserved for the captain's use, had in the case of smart ships long been dressed in uniform.

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* Since the date of the lecture, new specifications have been compiled by the Technical Co-ordinating Committee, in which scarlet cloths are numbered 1–5 and blues 1–15.

At one time, about 1779, the sailors wore a kind of kilt or petticoat. Before that the vogue was very loose slops like the petticoat breeches of the time of Charles II. In the reign of William IV, the facings were for a short time changed to red, but the last alterations to the uniforms were in 1856.

The uniform is made of a rough indigo blue serge, the chief type being 30 in. wide, 10 oz. in weight. Commissioned officers buy their clothes privately, but they are made of the finest wool dyed venetians, all of best indigo dye. Naval authorities are most exacting as to the dyes used and method of dyeing, and as the exact shades cannot be obtained with indigo alone, they specify what dyes may be used as topping and the maximum percentage. They also reserve the right to their officer of access to the manufacturer's or dyer's premises to view the process of manufacture or dyeing, at any time whilst their goods are being made or dyed.

The Air Force—The Royal Air Force was first clothed in the same uniform as the Regular Army, but later a new uniform was sought for the men. The officers first adopted a solid sky blue which made up very smartly with gold braid, etc. but eventually in 1923 to 1924 the present blue-grey was adopted. Officers' service dress is of a fine blue-grey worsted barathea, whilst the cloths for the men's uniform are similar to those worn in the Army, except they are a dark slate or blue-grey colour.

The Yeomen of the Guard or in full, The King's Bodyguard of the Yeomen of the Guard, was instituted by Henry VII in 1485. For over 250 years its duties were those of real guardians of the Sovereign in the palace, abroad, or on the field of battle, but now their functions are purely ceremonial; they attend levees and all State functions, such as opening of Parliament, and they also attend all the Courts.

Their dress consists of a black velvet hat of Tudor shape and fashion, with rosettes of red, white, and blue, small ruff, and scarlet tunic of fine cloth braided in black or dark blue velvet and gold braid, with crown, rose, thistle, and shamrock. The dress is just as it was devised by Henry VIII. The crown, rose, thistle, etc. embroidered with sequins or outlined with sequins. The tunic is made of cloth (scarlet No. 1) trimmed with silk velvet and gold braid of a special design.

Gold lace—Mention has been repeatedly made of gold lace. It is profusely used on uniforms, especially of bandsmen, drum majors, yeomen of the guard, and naval uniforms. This is of many designs, some universal, some particular to a regiment, and of various widths. The warp is either silk or cotton, dyed usually to tone with gold. The weft is the so-called gold wire, containing for the most part of 2·5% gold, 88% silver, and the rest alloy. An exception is made to this in the lace now being made for the Indian Government for use in India, for the Viceroy's Band, which is 5% gold and 85% silver. There are two kinds of lace, one used in the Royal Navy where the weft is actually wire (Fig. 8), but the kind usually employed for Army and State purposes has a weft of flat gold alloy spun on a silk or cotton core (Fig. 9).

The history of Army and Navy uniforms was kihdly supplied by Mr. Charles Hainsworth of Messrs. A. W. Hainsworth & Sons, Farsley, near Leeds.

[The Lecturer has deposited at the Institute a set of the Government specifications for clothing for the Services. These may be consulted in the Library.]

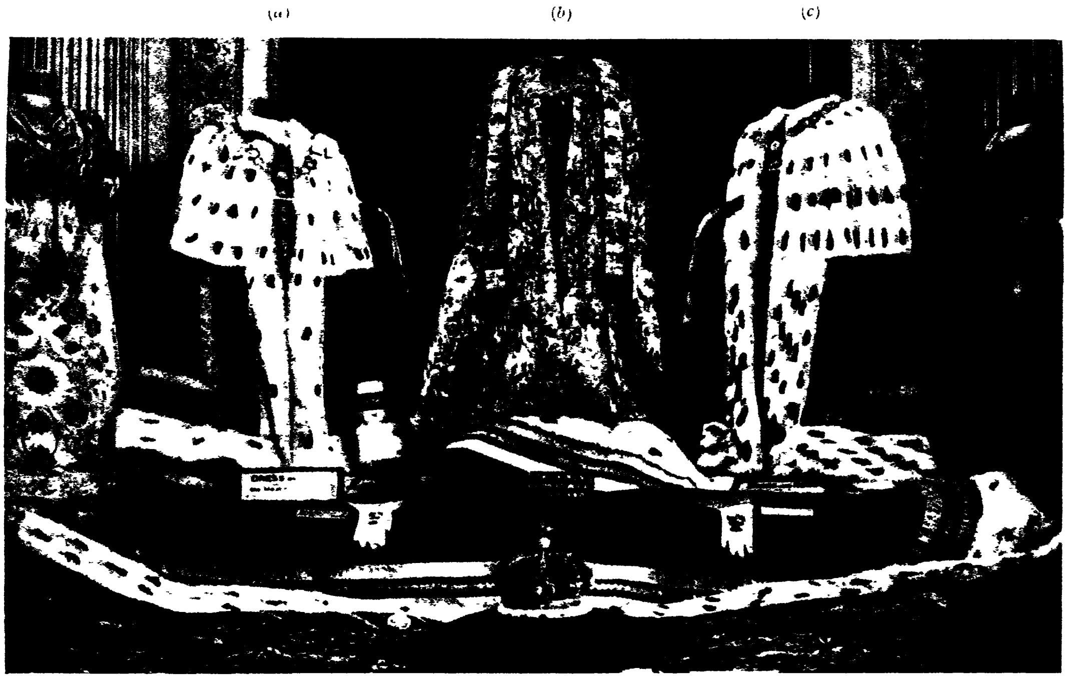

FIG 1

(a) Tunic and robe of purple velvet, trimmed with ermine, gold thread and gold braid, and caught back with white satin ribbon Ermine shoulder-cape and collar, long train Worn by H M. the King on the return from his coronation 1911

(b) Dalmatic of woven gold tissue with an arabesque pattern of brown silk, belt of cloth-of-gold with gold buckle Woven at Spitalfields Stole of woven gold tissue, ornamented with the white Imperial eagle, the Tudor rose, thistle, and shamrock, at each end the red cross of St George on a white ground. Woven at Spitalfields, the devices worked at the Royal School of Art Needlework

Imperial mantle of cloth-of-gold The design is a scroll of laurel covering the whole surface, leaving open spaces which enclose the white eagle, the Tudor rose the thistle, the shamrock, the royal crown, and the white lotus of India. Woven at Spitalfields, the devices worked at the Royal School of Art Needlework. Lined throughout with rose-coloured silk All worn by King Edward VII at his coronation

(c) Tunic and robe of purple velvet trimmed with ermine, gold thread, and gold braid, ermine shoulder-cape, long train. Worn by King Edward VII on the return from his coronation

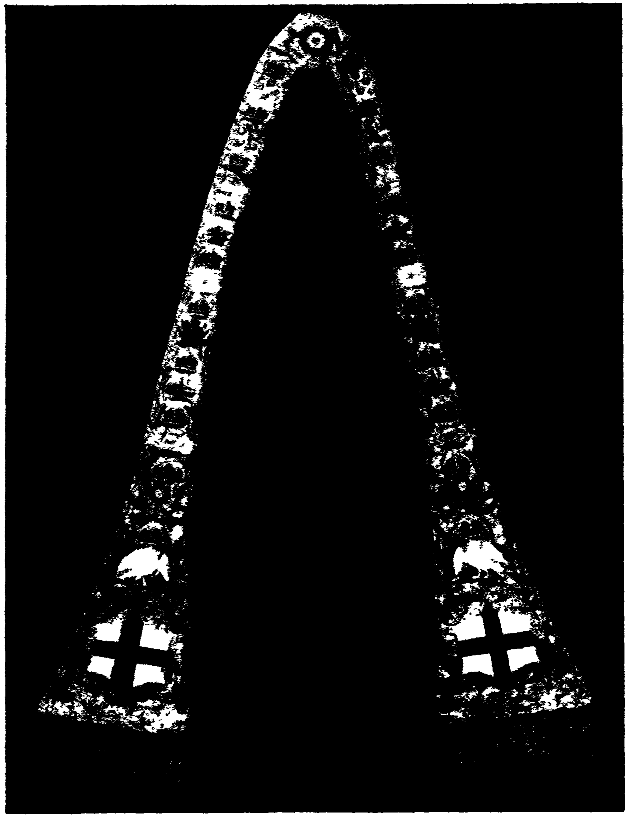

FIG 2

Coronation Stole of H.M. King George V Photograph lent by Messrs. Hobson & Sons, who embroidered the stole.

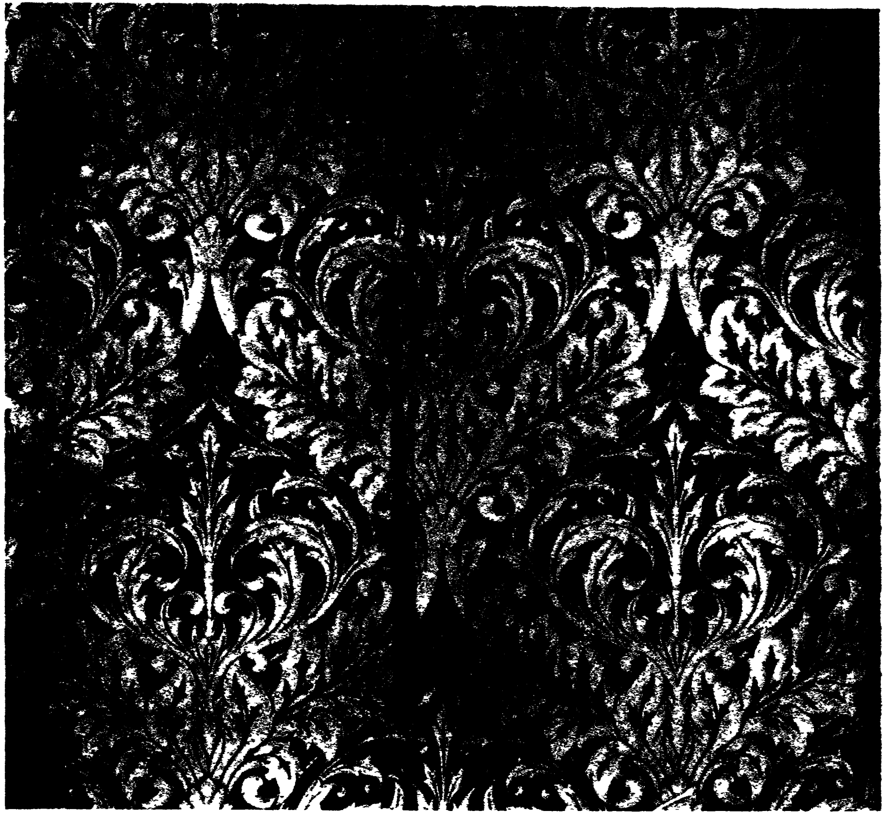

FIG 5

Specimen of silk damask
Lent by Messrs Warner & Sons Ltd., London

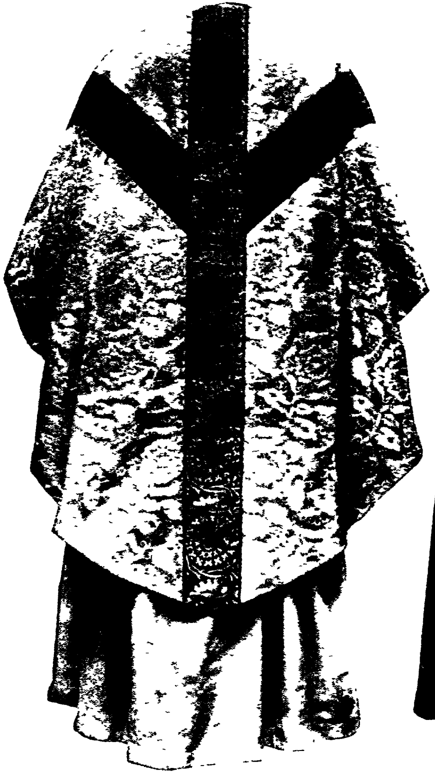

Fig. 3
Chasuble: large rose damask silk, with orphreys of brocatelle, edged cord and lined silk lining Block lent by A. R. Mowbray & Co Ltd., London

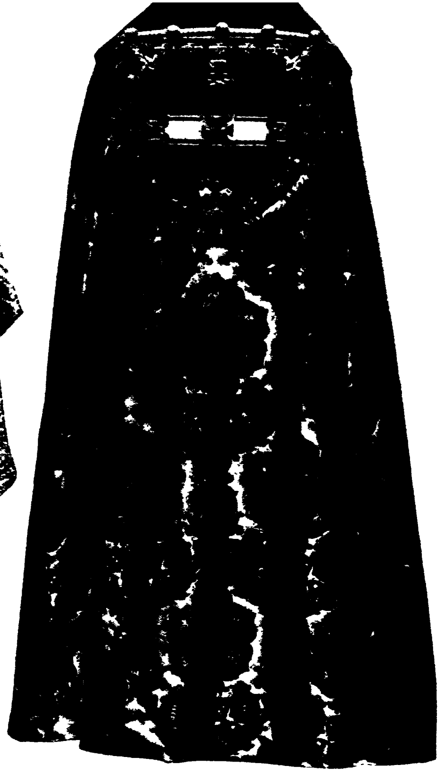

Fig. 4
Cope: of red and gold Gloucester brocade, with velvet orphreys edged jap gold braid; the hood and morse embroidered in rich design and colouring Lined throughout with silk faced lining Block lent by Messrs. A R Mowbray & Co Ltd , London.

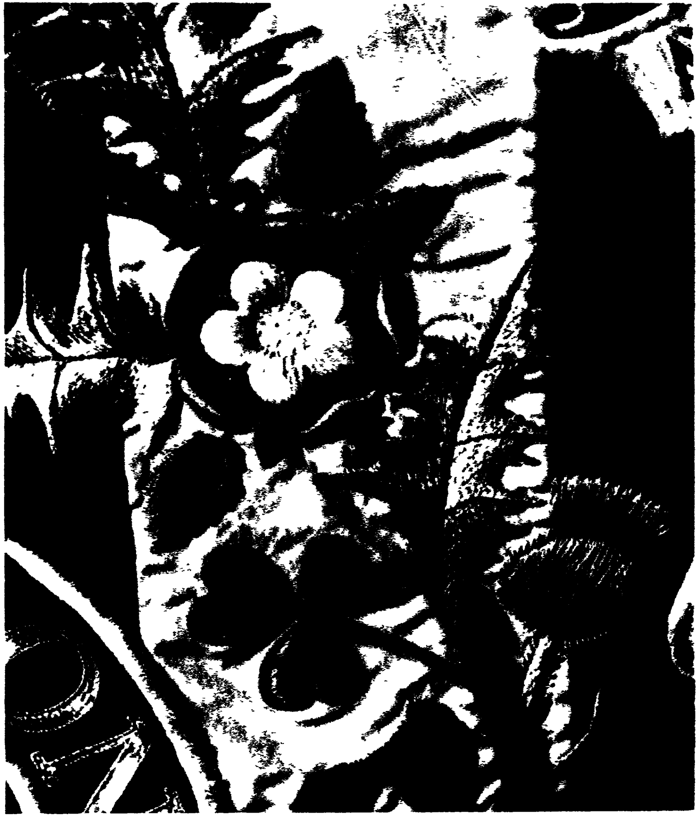

Fig. 7
Portion of a Regimental Colour to show embroidery.

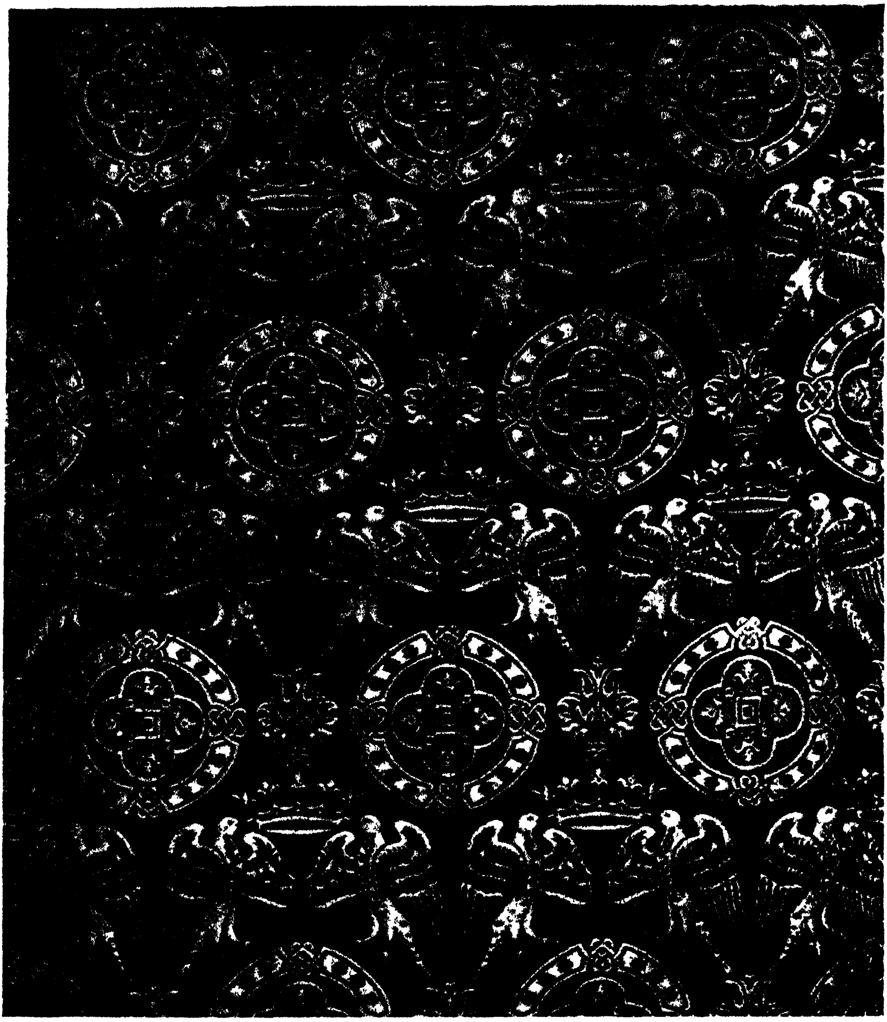

FIG. 6—Specimen of metal brocade Lent by Messrs Warner & Sons Ltd, London

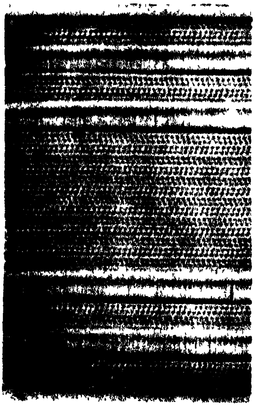

FIG. 8

Specimen of gold lace as used in
he Royal Navy; weft of gold wire.

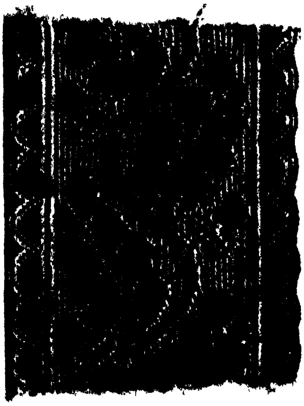

FIG. 9

Specimen of gold lace—oakleaf pattern
—used in the Army. Weft of gold alloy
spun on a silk core.

LANCASHIRE SECTION—VISIT TO WORKS

Opportunity of inspection of a factory concerned with the spinning and weaving of asbestos has not been frequently afforded. It was, doubtless, largely due to this consideration that a comparatively large number of acceptances were received in response to the generous invitation to members of the Lancashire Section of the Institute to visit the works of Messrs. Small & Parkes Ltd., at Hendham Vale, Manchester, on the afternoon of Wednesday, October 24th. Over 60 members attended and at the works were met by Mr. Geoffrey Parkes and afterwards conducted over the various departments in groups, accompanied by guides who described the various operations and processes. The departments covered asbestos spinning and weaving, and the manufacture of woven beltings, webbing, listings, and spindle tapes, and also brake linings and engine packings. Mr. Parkes traced the developments in connection with the factory and outlined the organisation involved and the gradual improvement proceeding in accommodation, building, and equipment. The inspection occupied about three hours and proved extremely interesting. Afterwards, the visitors were entertained to tea at the Grosvenor Hotel, Manchester, and, on the motion of Mr. W. Howarth (Bolton), seconded by Mr. Fletcher Chadwick (Preston), a hearty vote of thanks was passed to the firm for the facilities and hospitality afforded.

SCOTTISH SECTION—ANNUAL MEETING

The annual meeting took place at Edinburgh on the evening of October 19th. Mr. J. P. Beveridge presided and was supported by Mr. J. Macpherson Brown, Dr. Stevenson, Mr. A. W. Blair (Honorary Secretary), and others.

The Honorary Secretary reported that two meetings had been held in the year. The membership of the Section showed a slight reduction—84 in place of 88. There had been a few transfers of membership and these along with resignations and the addition of four new members left the position as stated. The finances of the Section were maintained at well within the limits of allowance. The total cost for the year was £10 4s. 11d., which represented 2s. 5¾d. per member.

On the motion of Mr. J. Macpherson Brown, the report and statement were accepted, and Mr. Blair was warmly thanked for his services. Mr. Brown added that he thought some of the visits to works had proved quite interesting. He firmly believed there was nothing lost in helping a competitor by way of exchange of ideas, and visits were most helpful in this respect.

The General Secretary (Mr. J. D. Athey) referred to Institute affairs generally and pointed out that of the 1,500 members there were now 178 Fellows and 312 Associates. As the professional body of textile technologists, the Institute had accepted responsibility for co-operation with the Board of Education in the conduct of a scheme of National Certificates in Textiles. Of late, the Institute had considerably extended the scope of its service to members by means of the library and its lending arrangements, the employment register, and the work of publication of scientific and technical literature.

The Honorary Secretary reported that there were no new nominations for the Section Committee which was re-elected as follows—Messrs. J. P. Beveridge, A. W. Blair, T. M. Lees, S. M. Roberts, Dr. A. W. Stevenson, and Andrew Smith.

It was announced that it was hoped to complete arrangements for meetings of the Section at Glasgow (December), Galashiels (January), and Edinburgh (February). A suggestion was also recorded in favour of a meeting at Carlisle—probably in March of next year.

A hearty vote of thanks was accorded the Chairman (Mr. Beveridge).

TEXTILE TEACHERS' ASSOCIATION

At the annual meeting of the Textile Teachers' Association (Lancashire), which took place at the Textile Institute, Manchester, on Saturday, 3rd November, there was an attendance of about fifty. Mr. J. Rostern (Radcliffe) was unanimously elected President for the ensuing year and Mr. T. E. Mitchell, F.T.I.

(Rochdale), the retiring President, was heartily thanked for his services. Mr. B. Hesketh (Farnworth) was elected Vice-President. The Competitions Committee of the Textile Institute had invited the views of the Association as to the suitability of the date of entry (30th June), and the date for submission of specimens. A further question referred to the Association was that of whether the Institute Competitions should be held annually or whether the regular interval of one year might be advantageously varied. Mr. J. D. Athey, Institute General Secretary, attended and explained the requirements of the Competitions Committee, mentioning that a similar request had been forwarded to the Teachers' Association for Yorkshire.

After discussion, from which it appeared there was considerable opinion in favour of maintenance of annual competitions, but with a change of dates of entry and closing, it was decided to refer the whole matter to a committee for consideration and report, perhaps by delegation, to the Institute Committee.

NOTES AND NOTICES

TEXTILE INSTITUTE ANNUAL COMPETITIONS

Fabrics, Yarns, and Designs for Printed Fabrics—Awards for 1934

The Competitions Committee of the Institute have concluded the adjudication of specimens submitted for the current year's competitions and the following awards are announced—

(A) Competition—Crompton Memorial Scheme—Woven Fabrics

First Prize (£30 and Certificate)—D. Johnston (Colne), Manchester College of Technology. Second Prize (£20 and Certificate)—Miss C. M. Mercer (Colne), Burnley Municipal College. Third Prize (£15 and Certificate)—J. H. Wilson, Burnley Municipal College. Prizes of £5 each—G. Gilyeat, Nelson Municipal Technical School; P. S. Cox, Nelson Municipal Technical School; G. Smith, Bolton Municipal Technical College; F. Farnell, Bradford Technical College.

(B) Competition—Novelty Folded Yarns

First Prize (£7)—W. G. Doidge, Blackburn Municipal Technical College. Second Prize (£5)—A. Dawber, Bolton Municipal Technical College. Third Prize (£3)—A. Styan, Bolton Municipal Technical College.

(C) Competition—Special Woven Fabric

First Prize (£7)—K. Priestley, Bradford Technical College. Second Prize (£5)—J. K. Senior, Dewsbury Municipal Technical College. Third Prizes (£3 each)—D. Johnston (Colne), Manchester College of Technology; E. W. Wood, Dewsbury Municipal Technical College.

(D) Competition—Woven Fabrics (Special Students)

First Prize (£5)—E. W. Wood, Dewsbury Municipal Technical College. Second Prize (£3)—C. F. Pickles, Burnley Municipal College. Third Prize (£2)—G. Pepper, Bradford Technical College.

(E) Competition—Knitted Fabric

First Prize (£7)—Not awarded. Second Prize (£5)—Miss P. I. Sankey, Leicester Colleges of Art and Technology. Third Prize (£3)—D. S. Williamson (Shipley), Bradford Technical College. Fourth Prize (£2)—Miss I. Weston, Leicester Colleges of Art and Technology.

(F) Competition—Designs for Printed Fabrics

Class I—Furnishing Fabric—First Prize (£7)—E. W. Wood, Dewsbury Municipal Technical College. Second Prize (£5)—Miss S. Dawson, Sheffield College of Arts and Crafts. Third Prize (£3)—J. R. Kemp, Manchester School of Art.

Class II—Dress Materials—First Prize (£7)—J. R. Kemp, Manchester School of Art. Second Prize (£5)—G. F. Ainscow, Rochdale School of Art. Third Prize (£3)—Miss M. L. Carquest, Sheffield College of Arts and Crafts.

Institute Annual Conference 1935

At the October meeting of Council, it was decided that the next Annual Conference shall take place in the latter part of Whit-week, June 1935. The official period of the conference proceedings will cover Wednesday 12th to Friday 14th June. The general subject to be dealt with by contributors of papers will be that of Conversion of Fibres into Yarns. The Council also decided that, provided satisfactory accommodation arrangements can be effected, the event shall take place at Ilkley. It was agreed that this Yorkshire inland health resort would provide a most convenient centre. Inquiries have indicated that excellent accommodation will be available at the Wells House Hotel, Ilkley, and the whole of the proceedings can be conducted on the premises named. Further announcement, with particulars, will appear in the *Journal* at an early date.

National Certificates in Textiles

The first batch of schemes presented for approval on the part of technical institutions came before the Joint Committee of representatives of the Board of Education and of the Textile Institute at a meeting held at Manchester on the 31st October. Recommendations were reached and duly forwarded to the Board. The early response to the facilities offered for establishment of National Certificates has been most favourable. A further instalment of applications for participation will come before the Joint Committee at a meeting to be held at the Institute's headquarters, Manchester, on the 11th December.

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application—

No. 121—Acting Under Manager (Sewing Cottons) desires similar position with good prospects. Matriculation, and City and G. Final "A" Cotton Spinning Certificate. Experience of Winding Machinery and Cotton and Rayon Dyeing. Age 19½

No. 122—Young man requires position where knowledge and experience would be useful. Associate of the Textile Institute. Two years' experience of Cotton Spinning and 11 years' experience of Cotton Weaving; knowledge of testing of all processes. Age 29.

No. 123—Young man (age 29) desires position as Weaving Manager or Assistant Weaving Manager. Associate of the Textile Institute. Leeds University Diploma in Textile Industries. Three years' experience of Loom Overlooking and five years' of Mill Managing.

New Members of the Institute

The number of applications for membership presented at the November meeting of Council formed the largest single month's record of accession of new members over a period of several years past. Twenty-five new members were elected and of this number 15 were elected to Ordinary and 10 to Junior membership. The following is a list of names of the newly-elected members—

Ordinary—F. A. Bak, 36 Stoughton Drive North, Leicester (Manager, Infants' Knitted Garment Dept., Alfred Yates & Co.); S. P. Baxter, "Glendene", Manchester Road, Linthwaite, near Huddersfield (Asst. Manager and Designer, Elon Crowther & Sons Ltd., Slaithwaite); L. Bellwood, 23 Spring View, Gildersome, near Leeds (Woollen and Worsted Cloth Designer, Henry Booth and Sons Ltd.); N. F. Bharucha, Jehangir Villa, 12 Club Road, Byculla, Bombay, India (Carding and Spinning Master and Supervisor, Moon Mills, Bombay); W. Buck, 47 Horace Street, Bolton (Powerloom Overlooker); C. T. Dracup, Samuel Dracup & Sons, Lane Close Mills, Great Horton, Bradford (Partner, Jacquard Machine Makers and Textile Engineers); G. J. Frankel, "Twyford", 41 Holmfield Road, Leicester (Technical Assistant, G. Stibbe & Co. Ltd., Leicester); R. S. Harrison, Bagot Street West Hallam, Derby (Chemist Dyer, on Research

Staff, British Celanese Ltd.); R. Porter, 72 Shepherd Cross Street, Bolton, Lancs. (Technical Assistant, British Cotton Industry Research Asscn.); F. V. Sellers, c/o Australian Woollen Mills Ltd., Sydenham Road, Marrickville, N.S.W., Australia (Designer); J. A. Service, Atlantic Mills, Bridgeton, Glasgow, S.E. (Director and Assistant Manager, D. & J. Anderson Ltd.); F. Sharples, Ashbrook Hey, Smallbridge, near Rochdale (Master Dyer, Sole Proprietor, Messrs. Robert Sharples); R. M. Thompson, Sandymount, Spencer Avenue, Leek, Staffs. (Joint General Manager, W. H. White & Sons, Knitted Outer-wear Factory); H. Wild, Celanese House, Hanover Square, London, W.1 (Manager, Yarn Development Dept.); N. Wilson, 16 Hodgson Fold, Bolton, Bradford, Yorks. (Worsted Spinning Manager, Charles Sykes & Co. Ltd.). *Junior*—Wm. Brooks, 30 Yarrow Road, Chorley, Lancs. (Under Carder); S. L. Grosman, College of Technology, Manchester 1 (Research Student); J. V. Hill, Textile Department, The University, Leeds (Student for B.Sc. degree); L. H. Kirkham, 30 Grosvenor Street, Leek, Staffs. (Designing and Colouring of Knitted Fabrics); C. Lord, "Fairhaven", Kingsley Grove, Audenshaw, Manchester (Director's Assistant, Salesman, etc., Ashworth Hadwen & Co. Ltd.); J. Ramsbottom, 97 Crumpsall Street, Bolton Spinning Room Operative); C. B. Stallard, 155 Beardall Street, Hucknall, Notts. (Departmental Manager, W. Reynolds & Co. (Hucknall) Ltd.); F. Stephenson, Linden Lea, Pawson Street, Morley (Asst. Mill Manager, R. J. Horsfall Ltd.); H. Vigrass, 4 Mount Vale, Novi Lane, Leek, Staffs. (Trainee, J. A. Vigrass & Co. Ltd.); R. T. Wrathall, 62 Underhill Avenue, Derby (Laboratory Assistant in Print Works).

Institute Membership—October

At the October meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—W. E. Ainscow, The Dell, Fall Birch Road, Lostock, Bolton (Cotton Manufacturer); J. M. Arnot, Hukumchand Jute Mills, Naihati, Bengal, India (Assistant Supervisor); E. H. Gomersall, 26 Upper Sackville Street, Skipton, Yorks. (Understudy to Thread Manager, J. Dewhurst & Sons Ltd.); H. B. Hopewell, 4 Richmond Road, Hinckley, Leicester (Department Manager, Simpkin, Son & Emery); Wm. Howell, 22 Holly Avenue, Walkden, Manchester (Power Loom Overlooker); H. G. Mather, Hillside Villas, Greengates, Bradford, Yorks. (Assistant Weaving Manager); K. J. Rao, Government Silk Weaving Factory, Mysore, S. India (in charge of Silk Throwing and Weaving Sections); F. Thomas, 20 Gregory Avenue, Bolton (Frame Overlooker, Bury Ring Mill Ltd.). *Junior*—J. Baxter, Alma House, Littlemoor Road, Pudsey, near Leeds (Wool Sorter); J. Emsley, junr., Temple Bank, Daisy Hill, Bradford, Yorks. (Spinner and Manufacturer); C. B. Good, 5 Blake Road, West Bridgford, Nottingham (in charge of small Dyeing plant, Wm. Gibson & Sons Ltd., Castle Donington); J. M. Pilling, 23 Sutherland Road, Bolton (Textile Student); E. H. D. Sugden, 10 Glenfield Road, Leicester (Hosiery Machine Tester and Mechanic); A. L. Le Rossignol, 1a Peveril Drive, The Park, Nottingham (Management of Testing Department); A. Tayler, 201 Copster Hill Road, Oldham (Textile Student); G. W. Worthington, 2 Brougham Street, Little Hulton, Bolton (Assistant Designer).

REVIEWS

The Selection of Colour Workers, being a Research into the Practical Methods of Measuring the Ability to Discriminate Fine Shades of Colour. Begun by A. M. Hudson Davies, M.A., and A. Stephenson, B.Sc., completed and described by W. O'D. Pierce, B.Sc.(Tech.), M.Sc. Published by Sir Isaac Pitman & Sons Ltd., London (134 pp., price 5s.).

Some in the British textile industry realise that much of its foreign trade has gone, probably for ever. Too few, however, appreciate that the situation is not by any means hopeless. It is to be expected that other nations will endeavour to supply the bulk of their needs of those materials which are most easily made.

On the other hand, processes requiring considerable manual skill and technical knowledge tend to be left to the peoples with generations of experience and a respect for scientific methods and research. There is still room for the specialist and pioneer in the textile industry. It is for this reason that we suggest the study of this book. An account of research work, it describes a method devised to measure ability to discriminate small differences in colour, gives details of the testing of some two hundred persons of different occupations, training, etc. and analyses the results. In some cases the results are compared with other pschycological tests. It demonstrates that skill in colour matching can be measured and indicates some of the factors that lead to or detract from exact colour discrimination. The result is that the standard of colour matching can be raised by selection of suitable workers, by appropriate training or by the regulation of working conditions. The use of statistical methods of analysis may render a study of the book arduous to some readers, but the conclusions drawn are sufficiently clear for the methods and their results to be of value to all. One may regret that the coloured patterns employed in the work were not as well graduated as is shown desirable in the analysis of their classification, also that fresh sets of specimens were not prepared. The results, however, justify publication at this stage, and it is to be hoped that by their publication facilities will be made available for repetition and amplification of work on the subject. F. W. B.

Industrial Maladies. By Sir Thomas Legge, C.B.E., M.D. (Oxon.), D.P.H. (Cantab), late H.M. Senior Medical Inspector of Factories. Edited by S. A. Henry, M.A., M.D., D.P.H. (Cantab.), D.T.M. (Liverpool), H.M. Inspector of Factories. Oxford University Press. 1934. (Pp. xiii+234, 12s. 6d. net.)

No persons more competent than the late Sir Thomas Legge and Dr. Henry to write about the many maladies which arise out of and in the course of industrial employment could easily be found. The author spent many years of his life in inquiring into the dangers of factory diseases and in devising means of preventing them, and the Editor is still actively engaged in the same work. The preface of the book is occupied by a memoir of Sir Thomas Legge's life, work and writings. It is a worthy tribute to a man of great achievements, and high ideals; and of a sense of duty which obliged him to resign his position at the Home Office because the Government would not ratify the attitude which he took up when representing it at the International Labour Conference at Geneva in 1921 on the measures to be taken to prevent poisoning by the use of white lead.

The book describes all forms of industrial diseases affecting any organ of the body, and not only of the skin which an important work recently reviewed in the *Journal* alone dealt with. Its opening chapters give useful advice on the notification of industrial diseases, and information about the procedure to be adopted in making, or resisting, a claim under the Workmen's Compensation Act. Another useful chapter is on the health and welfare conditions in factories and workshops, and the best methods to be adopted in the protection of the workmen from deleterious influences. The textile trades will be specially interested in the chapters on poisoning by fumes or gases, which has become more prevalent and varied in form since the introduction of artificial silk manufacture.

In the chapter on dust diseases, there is an account of the trouble formerly caused in card rooms to strippers and grinders from the dust created by their work. A large percentage of them suffered from asthma and bronchitis, and this can readily be believed by inspection of the illustration on page 196 of a carding machine in action before proper protective measures were taken to remove the dust by exhaust fans.

Twisters' cramp caused by the continued operation of twisting the ends of the warp of a woven piece with those of a new warp; and the deafness met with in a definite percentage of weavers who have worked ten years or more in the din of weaving sheds will interest readers of the *Journal*.

On the whole, it is a book of much practical value to anyone concerned with the management of factories of any description, and not only to their medical or scientific advisers who, however, will find it a useful addition to their own libraries. One, who had the pleasure of Sir Thomas Legge's acquaintance, will feel sure that he would have been gratified by the manner in which Dr. Henry has done his editorial work and the Oxford University Press has printed and published such a handsome volume. E. M. B.

A Century's Progress in Jute Manufacture, 1833-1933. By Thomas Woodhouse, F.T.I., and Alexander Brand, A.T.I. Published by David Winter & Son, Dundee. (183 pp. and index. Price 7s. 6d. net.)

The fact that 1933 marked the centenary of the jute industry in Dundee suggested this book to the authors who, therein, have put on record a survey of the outstanding phases and developments that have occurred during that period. The death of Mr. Woodhouse occurred before the book was finished, and it was seen through its publication stages by Mr. Brand. A brief and critical survey of the whole industry has been presented and special reference made to its modern position. The book is not strictly speaking a text-book and its historical aspects should command a wider distribution. At the same time, it should prove valuable to students as an introduction to the more detailed technical publications. On this account, therefore, a book at a less price would have appeared more desirable; students are, unfortunately, none too well-off these days, and publishers might show more consideration for their pockets. T.

GENERAL ITEMS AND REPORTS

MACHINERY AND ACCESSORIES EXHIBITION

City Hall, Manchester, 26th October to 6th November 1934

This Exhibition, organised jointly by the *Textile Mercury and Argus* and by Textile and Industrial Exhibitions Ltd., was opened by Mr. Richard Bond, President of the Manchester Chamber of Commerce, who expressed the opinion that the exhibition filled a most useful rôle in the life of the textile industry.

Though the number of exhibitors was smaller than usual and the absence of many leading British machinists was noted, there was nevertheless much of interest on view. A description of each stand was given in the catalogue* and amplifications have appeared since in the Trade Press. Space considerations, too, having to be made, it is not intended to repeat these descriptions in these pages. Reference will be made, therefore, only to those exhibits which seem to typify the lines upon which technical development has, of recent years, been proceeding.

Concentration of processing and co-ordination of the various stages between fibre and yarn was exemplified by the 2-part carding machine shown by William Tatham Ltd., of Rochdale. High-drafting, now well to the fore in every spinner's mind, was represented by frames shown by Casablancas High Draft Co. Ltd., of Manchester. One of the machines on view was a "super drafting" machine for which it was claimed that it suppressed three- or four-speed frame processes. An opening and dust-extraction machine for horse hair, African hair, wool, etc. was shown by Jakob Jaeggli & Cie, of Winterthur, Switzerland.

Winding, beaming, and warping have been engaging general attention in post-war years and several noteworthy examples of machines for such purposes were exhibited. The "Brugger" patent spindleless pirn winder was shown by John T. Murray, Manchester. Alois Schlick, of Burgstaedt i. Sa., Germany, showed a high-speed warping and beaming machine and universal SG creel. An Alliance, type 902, high-speed pirn winder by the Harrison Patent Knitting Machine Co. Ltd., Manchester; a hank-to-bobbin winder and a quick-traverse frame by Jakob Jaeggli & Cie, Winterthur; and cone and pirn winders by Schaerer-Nussbaumer and Co., Erlenbach-Zurich, Switzerland, constituted other evidence as to the general interest shown in this important aspect of textile production. Messrs. Prince-Smith & Stells Ltd., of Keighley, demonstrated the "Watson-Lister" high-production ring-twisting frame, and Messrs. W. & H. Frost & Co. Ltd., Barnsley, displayed a device for use with a standard winding machine, which ensures a uniform length of weft on every pirn.

The conversion of yarns into fabrics by weaving and/or knitting was catered for by various interesting exhibits. The desirability of utilising looms specially designed for rayon weaving has been emphasised of late years by more than one authority. Examples of such looms were to be seen on the stands of Jakob Jaeggli and Cie, of Wilson & Longbottom Ltd., Barnsley, and of Atelier de Construction Ruti, Zurich. Knitting machines were shown by the Harrison Patent Knitting Machine Co. Ltd., and by Messrs. Wildt & Co. Ltd., Leicester. Much interest was shown in the warp knitting machine demonstrated by Emil Wirth, of Hartmansdorf, Germany, which exemplified fabric production in a manner and with properties essentially different from its rivals, weaving and knitting. Warp-tying machines were shown by Barber-Colman Ltd., Manchester, and by the Uster Manufacturing Co., Zurich.

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* A copy is filed in the Institute Library—*Editor*.

Testing devices were displayed though somewhat restricted in scope. John T. Murray showed a twist-testing machine, a yarn tension meter, and two types of stroboscope—one electrically, and the other mechanically, driven. K. Szymanowski & Co. Ltd., Manchester, demonstrated an ingenious machine for determining rapidly, and sufficiently accurately, correct roller settings, drafts, and weights from the draw frame to the spinning frame. This firm also showed a draft resistance tester for roving.

Finishing machinery and accessories do not, perhaps, lend themselves to very definite display, and mention cannot be made of much of note in this section. Jakob Jaeggli & Cie showed a hank mercerising machine, whilst the piece-stamping machine of Henry Wallwork & Co. Ltd. was noted. The Amoa Chemical Co., of London, showed emulsifiers, softening, delustring, and proofing agents as well as wool oils and detergents.

Under the heading of Accessories, numerous exhibits could be grouped, though such classification in no way minimises their importance. Power production and transmission was represented by the motors of Brook Motors Ltd., Huddersfield; the Lancashire boilers of the Turbine Furnace Co., of London; by the composite display of steam, boiler, and gas equipment arranged by Ward Owen & Co., of Liverpool; by the steam purifier of Bolton's Superheater & Pipe Works Ltd., of Stockport; by the P.I.V. gears of J. Stone & Co. Ltd., of London; and by the belts and belting accessories shown by William Kenyon & Sons Ltd., of Dukinfield; Small & Parkes Ltd., of Hendham Vale; and W. T. Nicholson and Clipper Co. Ltd., of Salford.

Altogether a number of interesting exhibits was collected in the City Hall, and every augury—satisfied exhibitors and a good attendance of visitors—for a more representative show in future years, can be recorded. T.

REPORT OF THE SOCIETY OF DYERS AND COLOURISTS ON THE WORK OF ITS FASTNESS COMMITTEE

It will be generally conceded that in a matter of such general interest and importance as the fastness of dyed materials the standards set up should be free from all question of doubt or suspicion of bias. This means that the standards can only be framed by some independent body having no interests to serve, because even if the most reputable of firms were to undertake the task unkind people would be certain to accuse it of having some ulterior motive in mind. When, therefore, in 1927, the Council of the Society of Dyers and Colourists appointed a Special Committee to examine and report on "The Standardisation of the Fastness of Dyestuffs in Textiles", it acted not only wisely, but in a manner likely to yield great public service in a matter urgently in need of adjustment.

The Report is now to hand and deals with three fastness requirements, namely: Fastness to Light; Fastness to Perspiration; and Fastness to Washing. Five excellent illustrations of the instruments used follow the main report.

Fastness to Light

The Committee has evidently taken very great pains to render its results as free as possible from the criticism that in investigations such as these the information obtained is liable to be misleading owing to the fact that it is impossible to remove all variables. This kind of criticism has been met by instituting a very large number of experiments in different parts of the world and only the most carping critic will say that it has not been met adequately. Nevertheless, one fails to find any mention of the fact that any measures have been taken to standardise the dyestuff itself. Were these substances the commercial products? or were they subjected to special purification ? The matter is of importance because standardisation should be made good at every stage. The Committee adheres to the established international practice of employing 8 grades of fastness to light, No. 8 representing the highest grade.

The standards selected are—

Red Standards—(2) 0·5% Acid Magenta IIS (I.C.I.) (C.I. 692); (3) 0·5% Polar Red 3B Conc. (Gy.); (4) 1% Cloth Fast Red R (S.C.I.); (5) 1% Alizarine Rubinole GW (I.G.) (C.I. 1091); (6) 1% Kiton Fast Red 4BL (S.C.I.); (7) 1·2% Alizarine

Orange A425 Powder (I.C.I.) on zinc (C.I. 1033); (8) Durindone Red B400 Powder (I.C.I.) (C.I. 1207).

Blue Standards—(2) 0·5% Lissamine Violet 6BNS (I.C.I.) (C.I. 717); (3) 0·6% Brilliant Indocyanine 6B (I.G.); (4) 1·1% Polar Blue G. Conc. (Gy.); (5) 0·5% Solway Blue R.S. (I.C.I.) (C.I. 1076); (6) 2% Alizarine Light Blue 4GL (S.); (7) 4% Caledon Blue GCP300 Powder (I.C.I.) (C.I. 1113); (8) 3% Indigosol Blue AGG (D. & H.).

Fastness to Perspiration

It has been found possible to make up artificial test solutions representing Acid and Alkaline Perspiration based on the amazing results obtained by Voss and McSwiney in their investigations on the composition of human sweat. These solutions are—

Acid Perspiration Liquor—2·65 gm. NaCl per litre, 0·75 gm. Urea per litre brought to *pH* 5·6 with N/10 acetic acid solution.

Alkaline Perspiration Liquor—0·839 gm. NH_4Cl per litre; 1·732 gm. NaCl per litre, 0·424 c.c. 0·88 NH_3 solution per litre brought to *pH* 7·8 with N/10 acetic acid solution.

A schedule of tests is given indicating the manner in which these solutions should be used.

Fastness to Washing

"Four tests of increasing severity are prescribed and cover all degrees of severity from a mild home wash to a test representing the cumulative action of several severe power washes." Two sets of standards are then given, one in the red series and the other in the blue.

Every one concerned in the production of this excellent report is to be heartily congratulated. It will be of the greatest service to manufacturer and user alike and will be read with interest by all those concerned with colour chemistry. J. F. T.

EXHIBITION OF BRITISH ART IN INDUSTRY—1935

The Royal Academy of Arts in collaboration with the Royal Society of Arts is arranging this exhibition to be held at Burlington House from January to March 1935. The aim of the exhibition is threefold—

1—To impress upon the British as well as the foreign public both the importance of beauty in the articles they purchase, and the fact that British manufacturers, in co-operation with British artists, are capable of supplying such articles in all branches of industry.

2—To enable British manufacturers to study the full extent to which British artists are capable of supplying original, attractive, and technically suitable designs for the production of articles by mechanical means, and to turn the attention of British artists to design in relation to industry.

3—To show that a more frequent association of the artist's name with the article produced from his design can be of great advantage in promoting demand.

The exhibition is under the patronage of the King and Queen. Among the classes of articles to be included in the exhibition are dress materials; furnishing fabrics; carpets, rugs, etc.; ceramics, glassware, gold, silver and jewellery; leather-ware; printing (*a*) book production and (*b*) posters and commercial printing, etc.; domestic equipment and miscellaneous; furniture and interior decoration and plastic mouldings.

The arrangements are in the hands of a general Committee of which the Prince of Wales is President. Among the general conditions applicable to all exhibits are—

No works shall be considered for exhibition except such as are of original, contemporary, British design and manufacture. Exhibits must be designed by practising artists or designers who are of British nationality and established or employed within the United Kingdom of Great Britain and Northern Ireland.

Works shall be considered for inclusion in the Exhibition only if they have been manufactured within the United Kingdom by a British individual, firm, or company. A guarantee by the manufacturer to this effect shall accompany each article submitted, together with an indication of the source of the principal materials used. Where possible, preference will be given to works manufactured from materials originating in the British Empire. In addition to manufactured articles, the Exhibition Committee is prepared in special cases to consider a limited number of designs for such articles for inclusion in the Exhibition.

The name and address of the artist-designer shall be indicated in respect of each work submitted for consideration.

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PROCEEDINGS

TEXTILE INSTITUTE COMPETITIONS

DISTRIBUTION OF PRIZES

In the November issue of this Journal, page P398, a list of prize-winners in the Institute's Competitions appeared. The report of the Adjudicating Committee is now available and appears hereunder.

Report of Adjudication Committee

In regard to the principal competition (A), although the entries were somewhat less in number than usual, nevertheless, adequate compensation for this restriction is provided by the distinct advance achieved by the competitors in the matter of quality of exhibits. From the standpoint of commercial value, the consultative adjudicators on this aspect of the productions reported to the Competitions Committee that the specimens generally reached an unusually high level of merit. In arriving at the final list of awards, the Committee take into account the costing particulars accompanying two of the specimens, and in one outstanding instance loss of marks arose in this connection. After special consideration in regard to Design and Use of Colour, an advisory adjudicator reported an improved general standard of attainment with evidence of alertness and experimental endeavour to say something new.

The Novelty Yarns offered many interesting examples particularly in the matter of dealing with dissimilar fibres. The manner of presentation was not uniformly attractive, though one competitor made an excellent display by the aid of accompanying fabric specimens. The reminder may be usefully made that the employment of many ends in a yarn militates against commercial application. In one or two instances, marks were lost owing to absence of definite statement of claim as to the uses of the yarns.

The competitions for designs for Printed Fabrics proved a little disappointing so far as Class I (Furnishing Fabric) was concerned. It is felt that too few of the competitors have taken up the attitude of prospective purchaser—an attitude the adoption of which might have yielded evidence of more purposeful outlook. Generally, however, the workmanship was good. In Class II (Dress Materials) there was improvement in inventiveness and the designs were in keeping with current styles.

In the (C) Competition for Woven Fabric of distinctive character or structure, keen rivalry prevailed and several competitors had exercised marked resourcefulness. A few of the exhibits, however, lacked adequacy of statement of claim and the importance of this condition cannot be over-emphasised.

The woven fabrics submitted by examinees of the City and Guilds of London Institute were generally of much greater merit than previously.

The contest for Knitted Fabrics fell somewhat below the general average in one particular respect—structural interest. The importance of this feature is to be emphasised in the conditions issued in future. It is interesting that the field of competition appears to be widening.

The Committee offers warmest thanks to all who assisted in the work of adjudication.

Distribution of Prizes

This event took place on the Saturday afternoon, 8th December, when the President, Sir Thomas Robinson, presided. In his opening remarks, Sir Thomas said that we were engaged in a depressed industry, but we must not lose heart. Regarding the cotton section, he cited the following particulars relative to exports. The yardage exported in the following classes—Grey; Bleached; Printed and Dyed—fell considerably in 1933 and 1934, as compared with the average yardage exported for the four years 1910–1913. It was true that since 1914 great developments in textile production had increased throughout the world. New nationhoods who have come into being had developed the industry, and they had the advantage of the latest methods and most modern plant to balance. The nations of the Far East were our greatest rivals. Japan had progressed at a remarkable pace. Developments within China and India were also factors to be considered. The Eastern World, with its manner of life, general economy, and low cost of production, jeopardised the premier position we held in the world's markets for the lower grades of textile fabric.

From the economic viewpoint, we were living in a new world as compared with 1914. He still believed that there was a future for British textiles, especially in every class of super fabrics. There was, therefore, a greater need to-day for us to put in the industry our best brains. Necessity for technical knowledge in the industry in every branch is greater to-day than ever before.

The Textile Institute would serve a great purpose in the future by continuing to promote technical knowledge in all the sections of construction of fabrics and production, and thereby contribute its quota to conserving the position which he believed we held in the world's markets for super textile fabrics. Artificial silk 100% and mixtures offered a very large field of development. These fabrics had attracted a very large demand throughout the world, and in this field there was great scope for British brains and experience.

In conclusion, Sir Thomas said it is for everyone to strive to give to the industry their best thinking, and thereby contribute their quota to the conservation of the industry. He then called upon Mr. W. M. Whitehead, Principal of the Burnley School of Arts and Crafts, and President of the National Society of Art Masters, to present the prizes.

Mr. Whitehead after presenting the prizes made some observations on Design particularly in relation to woven textile fabrics. He said that textile design, especially for jacquard products, had been very largely a "kind of flower obsession." The type of pattern in which growing plants and birds and such like were used had enjoyed a disproportionate popularity and seemed to be regarded as equally suitable for wallpapers, carpets, furnishings, embroideries, textiles, and indeed for every flatly-decorated article. Design was visualised as something applied to a material; a "stuck-on" decoration.

He said that he was concerned at the moment with design for textiles, or more appropriately, design in textile fabric. The fabric was a structure and appropriate design should evolve out of the structure. Fabric structure did not suggest plants and birds and animals. It was true that the jacquard mechanism of the loom could be manipulated so as to produce forms that had a resemblance to growing natural specimens. A great many materials and mechanism could be made to imitate natural forms in this manner of decoration, but it was not good craftsmanship and in consequence was frequently bad design. In textiles the interweaving of weft and warp should be alike the structure and the inspiration of the pattern.

We sometimes studied the efforts of primitive weavers, largely because we wanted to weave their fabrics and sell them to primitive people. In this way we frequently produced the best textile design. If we studied the fabric products of primitive people now and again, not merely to sell them something but to find out how they proceeded in design, something valuable might be learned for the textile industry which, if it had been learned before, had in practice been almost neglected. Some examples of a departure from the traditional flower patterns had been seen and these were usually described as modern designs. The moment a textile design departed from the style of pattern used in mediæval and Renaissance times, the design was considered to be modern. Modernity in design was like the modern music; it was really primitive.

Another direction, continued Mr. Whitehead, in which we might experiment was in regard to Colour. In this aspect in particular, the schools of art working in close touch with technical schools could be of substantial assistance. A combination of colours devised on paper was considerably modified when made up in the fabric. Furthermore, the play of light and shade on the fabric structure tended to give new values to colour combinations. In spite of these things experimental colour work on paper had a value in stimulating a freshness in the use of colour, and should be practised by designers of textiles.

Mr. John Crompton, chairman of the Competitions Committee, in moving a vote of thanks to the President and Mr. Whitehead, said that textile manufacturers were now looking more to the technical colleges to help them to produce designs out of the ordinary run—something of a character which required great taste and practical ability. Costing formed an important part of the competition, as a designer should know how to produce a fabric at a given cost. With regard to practical application of design, he instanced the work of Miss Mercer on shoe fabrics. He also referred to the fabric designed by Andrew Millin which was awarded the first prize (£7) in (C) Competition last year (1933), and said that it had been accepted for the Royal Academy Exhibition of British Art in Industry which opened in January 1935.

Mr. Frank Wright seconded, and asked those present not to be obsessed with the idea that mass production would save the Country. It would not. He did not entirely agree with Mr. Whitehead regarding the forms of flowers in design; he found them very pleasing. Heavy responsibilities rested on the young people to carry on the work in connection with which scientific investigation was continuously making discoveries.

After being supported by Mr. W. W. L. Lishman, the resolution was carried with acclamation.

London Section

Meeting held at the Clothworkers' Hall, Mincing Lane, London, on Wednesday, 21st March 1934

THE CLOTHWORKERS' COMPANY

The following report is abstracted from the text of an address* delivered to members of the London Section and friends by P. M. Evans, Esq., C.B.E. formerly Clerk to the Company.

The Clothworkers' Company was formed by the union in 1527, of the Fullers' Company and the Shearmen's Company during the reign of Henry VIII, these two companies being then incorporated under the title of "the Guild or Fraternity of the Assumption of the Blessed Virgin Mary of Clothworkers in the City of London," which by the Charter 24, April 9, Charles I (1634), was altered into the present title, namely "The Master Wardens and Commonalty of Freemen of the Art or Mystery of Clothworkers of the City of London." The original Charter of the Fullers' Company was dated the 28th April 1480, being granted by Edward IV, while the Charter of the Shearmen's Company, which was dated 24th January 1507/8, was granted by Henry VII. These two companies were branches of the Weavers' Company, which claims to be the oldest of the City Guilds and whose Charter, granted by Henry II, indicates by recitals that this Company was in existence in the reign of Henry I (1100–1135).

Other branches of the Weavers' Company connected with the cloth industry were—

The Burllers, whose business was to measure the cloth—and so named from "burrell" the width of two ells from list to list of the cloth, and

The Testers (workers of cloth of worsted).

These two branches eventually amalgamated with the Drapers and Merchant Taylors' Companies.

The Gilds or Guilds of London existed as Brotherhoods or Fraternities of men and women living in the same quarter of the City and contributing towards a common stock for centuries before their incorporation. Originally, they were associations of persons actually professing the trades from which they took their denomination, with this important and essential incident, that the membership or freedom of the "gild" was transmitted on the principle of hereditary succession, side by side with the system of apprenticeship or trade adoption engrafted thereon. Herbert† indicates that the name "Gild" is derived from the Saxon word "Gildan", to pay, denoting an associated body or brotherhood, because every member was "Gildar", *i.e.* to pay something towards the charge and support of such body. These "Gilds" were not trading, but were trade societies and their objects were—

(i) To protect the consumer or the employer against the incompetency or fraud of the dealer or the artisan, to ensure that the goods put up for sale were of true texture and weight, and to secure a maintenance to the workmen by preventing his being under-sold in the labour market by an unlimited number of competitors.

(ii) To act as a domestic tribunal for the settlement by arbitration of disputes between man and man thus diminishing hostile litigation and promoting amity and goodwill.

(iii) To perform the functions of a Benefit Society from which the workman, in return for his contributions, might be relieved in sickness or infirmity, or old age, and have his burial expenses paid.

(iv) To serve as Institutions, as in the nature of a modern club, in which individuals of the same class and their families might assemble in social intercourse.

(v) They had also a religious element—the patron Saint of the Fullers' and Shearmen, and of their successors the "Clothworkers' Company" being the Virgin Mary.

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* Published in full by the Clothworkers' Company.

† History of the Livery Companies. Vol. I, pp. 1–3.

Of the above mentioned objects, (i) and (ii) have for some time fallen into disuse—the privilege of searching for bad workmanship having been discontinued about the middle of the eighteenth century, doubts having arisen as to the Company's powers in this direction as a matter of law. Objects (iii) and (iv) have always been, and are still, being fulfilled by the Companies.

There were, apparently, three kinds of Guilds existing in Anglo-Saxon times. First came the political Guilds, or as they were styled later the "Frithgilds" owing to the peculiar nature of their constitution which was founded on certain pledges; secondly the Ecclesiastical Guilds; and thirdly the Secular Guilds (the main object of the lecture), the latter being somewhat the junior as regards age.

The Secular Guilds increased in importance as time went on and attained a still more prominent position in the reign of Edward III, who recognised that they were rapidly becoming the mainspring of the trade of the Kingdom, and showed his royal favour by becoming a brother of one of these societies. It was also about this time that the Guilds became known as "crafts or mysteries" in substitution for the name "Gilds," assumed a distinctive dress or livery (a privilege included in their Charters), and became thenceforth known as "Livery Companies." It was probably towards the end of this reign or during the following reign of Richard II, that steps were taken by the Government to compel the various companies to enrol their Charters, and that the separation of the wealthier from the poorer companies took place, the former then being generally referred to as "the Great Companies".

The government of these companies was as laid down in their Charters, by-laws, and ordinances, which, besides providing for the keeping of trade secrets the regulation of apprenticeships, the management of the Company and its special concerns, also dealt, *inter alia*, with the regulation of their religious and other ceremonies.

The officers consisted of—

The Alderman, now known as "The Master" or "Prime Warden", and the Wardens.
The Bedel or Beadle.
The Priest or Chaplain.
The Clerk.
Assistants, whose duties it was to help and assist the Master and Wardens in carrying out their duties.

Strict performance by the Members of the Company of the duties of their offices was enjoined, and in contrast to present practice, non-fulfilment or non-acceptance of these duties was visited by fine.

It may be of interest to note the description given by Herbert* of a pageant exhibited by the Clothworkers Company in 1694. It runs as follows—

> "The Clothworkers, in 1694, after an allegorical representation of London, exhibited the garden of the Hesperides, with Jason and his golden fleece. Then the chariot of Apollo, of magnificent appointments, drawn by two golden griffins (the Company's supporters) mounted by triumphant figures. Apollo himself, allegorically connected with the Company, as the shepherd of King Admetus, rode in the chariot, and whilst addressing the Lord Mayor, a rich figure of a rising sun, above ten foot diameter, not seen before—and whose beams cherish both sheep and shepherd—appeared above his head out of the back of the chariot, with all his beams displayed in gold.
>
> The Trade pageant expressed the whole art and mystery of the Clothworkers, by all manner of persons actually concerned in all branches of the trade, as carding, combing, spinning, rolling, shearing of wool, etc."

The Livery Companies experienced a very serious set-back as the result of the Reformation. Most of the properties which they held had been subjected by the donors to some religious obligations (commonly termed "obits" or "chantries") and became forfeited to the Crown. The respective companies had to raise the necessary moneys for their repurchase and were only able to do so with much difficulty and at great sacrifice. A further trouble which arose was that the Crown adopted the practice of extracting from the Livery Companies money for various purposes, such as setting the poor to work; erecting the Royal Exchange; furnishing military and naval armaments; protection of the City; provision of coals and corn; and State lotteries. This money was ostensibly by way of loan, but a request in 1561 for some return appears to have been barren of result, and there is little doubt that not much was ever recovered.

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* *ibid*, pp. 206–207.

Attempts were also made by the Government to interfere with the management of the affairs of the companies, by endeavours to control the disposition of their property, and to influence the election of the officers, several instances of the latter being recorded.

An ingenious scheme of James I for making further use of the City Companies was what is known as the Ulster Plantation, by which land in Ulster forfeited to the Crown as the result of rebellion was offered to the Corporation and the City Companies for colonisation. To carry out this scheme the Irish Society (which is still in existence) was formed. Each company took shares, some of the smaller companies being associated with one of the twelve Great Companies. In spite of trouble with Charles I, the city and the companies faithfully carried out their obligations, to the great advantage and prosperity of that portion of Ireland. Out of compliment to the new landowners, the chief town of Derry was re-named Londonderry. Apart from the Irish Society, which is controlled by the Corporation of London, few, if any, of the City Companies still retain their original holdings.

As already mentioned, the two Companies—the Fullers and the Shearmen—were incorporated as the Clothworkers' Company by a Charter granted by Henry VIII in 1527/8. By this, and by subsequent Charters, certain privileges were conferred upon the company, the following being some of the more important—

(i) The Company was to elect and have a Master and four Wardens.
(ii) Perpetual succession and a common seal.
(iii) Power to purchase and hold Lands, Tenements, Rents, Annuities, Services, Hereditaments, Goods, Chattels and other possessions, which included the holding of the possessions of the Fullers and Shearmen.
(iv) Power to plead and be impleaded in the Courts of Law by their name—The Master Wardens and Commonalty of Freemen of the Art or Mystery of Clothworkers of the City of London.
(v) Power to increase the Commonalty (*i.e.* the Freemen) and to receive into it natives as well as strangers.
(vi) Power to hold honest and lawful meetings, and to make statutes and ordinances for the government of the Company.
(vii) Power every year or every two years or otherwise at their pleasure to have one Livery or garment of one suit most suitable for the purpose.
(viii) Authority to keep "a Feast or Entertainment of meat and drink in a fit place at the feast (29th June) of Saint Peter ad Vincula, or thereabouts."
(ix) Power of search within the City of London, the Liberties and suburbs thereof "or in any other place throughout the space of three miles distant from the City of London, with the further power of the correction and punishment of all persons as well Freemen Natives as Foreigners and strangers, for their offences to be done in this behalf in and for not perfectly working, executing, exercising and performing in the working of Woollen cloths, Fustians and other things whatsoever howsoever concerning and touching any of the said arts or mysteries aforesaid."
(x) Members of the Company were to pay two shillings quarterly (commonly known as quarterage) for the support and maintenance of the Company, a charge which is still made when any admission to the freedom takes place. A power of distress was also given in case of non-payment.
(xi) The admission of women to the freedom of the Company was also recognised in the Charters.

Membership of the company was also made compulsory for anyone intending to carry on these trades.

The by-laws and ordinances of the Clothworkers' Company were in accordance with the requirements of the Act of Parliament 19, Henry VII, duly passed by the Lord Keeper of the Great Seal of England and the Chief Justices of the King's Bench and Court of Common Pleas in 1639 (15. Charles I). The recital in the document approving these by-laws and ordinances describes them as—

> "made ordayned and devised for the better rule order and government of the said Company or Fellowship of Cloathworkers and their successors and of such others as now doe use or which hereafter shall use the Arte or Mistery of Cloathworkers within the City of London the suburbs and precincts of the same or within such other place as by the laws of the Realme the said Company are privileged and authorised and for the common weale and conservation of the said Art or Mystery of Cloathworkers."

They provide, *inter alia*, for—

(i) the holding of meetings;

(ii) the yearly election of Master and Wardens (whose titles and duties are specially indicated) and the appointment of deputies. Members of the Livery were required to attend

> "from the houre of eight of the clocke in the morning" of election day until the election was finished, and to go with the Master and Wardens by two and two orderly and decently "in their best Livery from their said Hall unto Saint Dunstons Church in the East or such other place or parish Church as shall be by them in that behalf appointed to hear divine service or some Godly sermon or both and shall in like decent order retourne from thence unto their common Hall back again to doe and exercise such other necessary business as to them shall seeme meet and so to dynner or drinking there and not to depart thence without licence of the Master and Wardens until dynner or drinking be ended the same day."

(iii) the fines payable on non-acceptance of office;

(iv) the constitution of the Court of Assistants (consisting of those who had served or fined for non-service, together with any Members of the Livery specially elected); the removal of anyone adjudged to be a notorious evil liver being duly provided for;

(v) election to the Livery of the Company and the fine payable on admittance;

(vi) the appointment from the Livery of Stewards, whose duty it was to provide a dinner for the Master Wardens and Livery, or in default pay a fine of £25;

(vii) the election of "one honest, discreet and sufficient" Clerk and the election of Beadle;

(viii) the keeping of the "foure quarterdayes of assemblies;"

(ix) the payment of quarterage and various fines;

(x) provisions as to search;

(xi) provisions for the relief and burial of poor members;

(xii) prevention of change of freedom without licence;

(xiii) the oaths to be taken by the various officers and on admission to the freedom of the Company;

(xiv) power to admit by redemption;

(xv) provisions and restrictions as regards apprenticeships which limited the number to be employed and prohibited the apprentice being lent out or allowed to perform any work done by divers porters, waterbearers and others;

(xvi) provisions and restrictions as regards trading, the more interesting ones being those which provided—
    (*a*) that none should entice away another man's servant;
    (*b*) that no journeyman of the Company should work with one of another Fellowship when he might have reasonable wages with one of his own company;
    (*c*) that none should colour any Forreyners goods or teach them their trade;
    (*d*) prohibiting work on Sundays;

(xvii) regulations for general behaviour—*e.g.* the punishment

> "of such as shall be obstinate or unrulie" or "use any undecent or uncomely speeches";

(xviii) suspension from office or membership of Livery on disclosure of trade secrets;

(xix) the quorum necessary to constitute a Court, *viz.*—

"The Master or his Deputy and the foure Wardens or two of them att the least, and twelve of the Assistants att the least";

(xx) provision for fining any Master or Warden who may be remiss or partial in executing the ordinances.

Concurrently with the growth of the clothworking industry, the Clothworkers' Company increased in power and influence, and there is no doubt that in the fourteenth and fifteenth centuries both clothiers and clothworkers were in prosperous circumstances.

The present constitution of the Company has varied little if at all from what is laid down in the Charters and by-laws. It is at present made up as follows—

The Master, who is elected annually and serves for one year.

The 4 Wardens, who serve for two years—two of the "ancientest meetest and ablest" of the Livery being elected each year as Junior Wardens.

The Court of Assistants, composed of those members who have served or fined for the above offices.

The Livery, to which freemen are admitted annually by election at the discretion of the Court.

The freemen and freewomen.

The government of the Company and the management of its affairs and property is, as in the past, in the hands of the Master Wardens and Court of Assistants, and is now carried out by the Court of the Company and its standing Committees.

Membership of the Company, that is to say admission to the freedom, is and always has been, acquired

By Patrimony—This right has always been transmitted on the principle of hereditary succession, and a child born after his or her father's admission as a member is entitled on attaining 21 to come and claim this privilege.

By Apprenticeship, or Servitude, as it was called in the old days—This method of recruiting its members was, as has already been mentioned, regulated by the by-laws and ordinances of the Company, the duties and responsibilities of both Master and apprentice being very strictly defined and limited.

By Purchase or Redemption—The Court of the Company were also given the power under the said ordinances "to receive and take from time to time into this company or fellowship, by way of compositions and redemption, such person or persons as to them shall seem meet and convenient."

The income of the company was and is still derived from (1) the Trust Estates; and (2) its Corporate Estate.

It is stated in the returns made to the City Livery Companies Commission (29th July, 1880) that "there is no single instance known of any property, real or personal, coming to the company from persons outside the livery of the company, except for valuable consideration or charitable uses and it will be seen likewise, from the memorandum annexed to the return of charitable trusts, that these were bequeathed by benevolent persons, who with one or two exceptions were in their time Masters or Wardens; and there have been several recent instances of benefactions to the Company absolutely, as well as on charitable trusts, of various kinds."

The Trust Estates and Endowments are held on various charitable trusts, some for the benefit of poor Clothworkers, some educational, and some for the benefit of blind persons. Their administration is, of course, subject to the control, of the Board of Charity Commissioners and under the Company's management they have considerably increased in value.

The Corporate Estate represents properties given or bequeathed to the Company for its sole private use and benefit and is free from any trust. This property, by careful administration, has also grown to considerable value and the income therefrom is used in supplementing the trust funds, and in promoting other charitable and beneficial objects.

The site on which the Company's Hall stands was conveyed to the Shearmen's Company by deed, dated 15th July 1456. The present hall is the third hall that has been erected on the site. (The Hall of the Fullers' Company was in Billiter Street). The first hall was probably built about 1482 and was more or less destroyed in the Great Fire, as is described by Samuel Pepys (who was Master of the Company 1677/8) in his diary. Speaking of the fire, Pepys said—"But strange it is to see Clothworkers' Hall on fire these three days and nights in one body of flames, it having the cellars full of oyle." The second Hall which was erected in 1708 was pulled down in 1857, partly, I believe, because it was more or less condemned as unsafe and partly because it did not afford sufficient accommodation. The present hall was opened in 1860, an inauguration dinner being held on the 27th March of that year, which was honoured by the presence of The Prince Consort, who had previously accepted the presentation of the Honorary Freedom and Livery of the Company.

King James I became a Freeman of the Company in 1607. At the same time, it is understood, he promised the Company "two brace of bucks yearly for ever"—a promise which like many others appears to have been more honoured by the breach than the observance.

[At this point in his address, Mr. Evans made brief reference to the banners in the hall, the iron chest in the vestibule, the books containing the early history of the Company, and to various paintings and portraits displayed on the walls.]

The decay of the Gilds' Industrial Organisation took place, according to Froude,* in the reign of Elizabeth. It is said that the Queen "sent to the Mercers' Company to know why silks were so dear, and marvelled much to learn that only one or two of the Company knew anything about silks at all." It also appears from the books of the Clothworkers' Company that of the five persons named as Master and Wardens in the Charter of Queen Elizabeth, A.D. 1560, one only was a clothworker by trade. The Gilds, however, while having for the most part only a nominal connection with their trade, continued as nurseries of charity or education and seminaries of good citizenship, helping with such grants as lay in their power all public and patriotic objects.

Coming down to more modern times, it is submitted that the record of the Clothworkers' Company will bear the closest investigation. The care of its poorer members has been one of the main objects of the Company from time immemorial, and help and assistance is given in several ways, *e.g.* grant of pensions or appointment to one of the Company's almshouses in old age; help towards the better education of their children; and special allowances in case of need.

In addition to the above, the principal activities of the Company include the following, viz.

Secondary and Higher Education—The Company has scholarships for women, tenable at the Colleges of Girton and Newnham, Cambridge, and Somerville, Oxford, besides helping these and other colleges and schools by special grants. It also awards leaving exhibitions to girls from schools in which it is interested as trustee or otherwise. It owned, and for several years controlled, the Mary Datchelor Girls' School at Camberwell, to which it made considerable grants for improvement of the school buildings. The school is now aided by grants from the London County Council, but the Company is still responsible for the management of the school, which is now controlled by a representative body of managers upon which the Company has the principal representation.

Technical Education—With others of the City Gilds, the Clothworkers' Company was a pioneer in promoting technical education generally, which in London has taken the form of the City and Gilds of London Institute. To this the Company give a maintenance grant of £3,000 a year, its total contributions in respect of building grants and maintenance being at the moment about £230,000.

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* History of England. Vol. I, p. 50.

The Clothworkers' Company has done all that has been possible to foster the trade with which it was originally connected, and I do not think that there has been any Technical Institute started which has had a textile and dyeing section, which has not at some time or other been helped by the Company. Large grants have, from time to time, been made to Technical Institutes in Yorkshire and elsewhere, and were continued until these organisations became rate-aided. The Court of the Company then concentrated on the departments which they had built, equipped, and maintained at the University of Leeds.

The Textile Industries Department and The Colour Chemistry and Dyeing Department of the University of Leeds, which have a world-wide reputation, owe their existence to the Clothworkers' Company. Started in 1874 in one room, they have continually expanded, each expansion being provided for by increased maintenance or building grants from the Company, the last occasion being as recently as 1928, when about £17,000 was allocated by the Company to building extensions and £1,300 to equipment. The maintenance grant which in 1904 was £4,000 was temporarily increased by £3,000 a few years ago, and last year a further experimental grant of £3,000 a year was made for the promotion of additional research—a total at the moment of £10,000 a year. Reports from the University show that valuable research work is being carried out in these departments through the assistance of this additional grant. Altogether the Company have spent on these departments a total of approximately £314,000.

The Company is keenly interested in the welfare of the blind, and administers considerable trust funds left for pensions for the blind by various members of the Company. Every year a sum approaching £12,000 is distributed in such pensions.

Grants are also made every year to hospitals and other miscellaneous institutions, as well as in response to the many appeals for charitable and philanthropic objects. In short, after deducting the somewhat heavy charges for rates and taxes on the real estate, a sum varying from one third to one half of the Company's corporate income is devoted to public services.

No charge is made for the management of the Trust properties, the whole of the income being therefore available for the beneficiaries. In the case of trusts, where the object has failed or become obsolete, new schemes have on the application of the Company been formulated by the Charity Commissioners in accordance with what is known as the "Cy pres" doctrine enabling the funds to be usefully employed in meeting changed conditions, but at the same time paying due regard to the spirit which prompted the original gift.

[Mr. Evans next drew attention to the plate either formerly owned by, or now in possession of, the Company and described the more interesting pieces, many of which were on view.]

I should perhaps have recorded, he continued, that this Company is the twelfth in order of precedence of the twelve Great Companies; this order of precedence being according to Herbert* "sette ordeyned and agreed" in 1514/5, by Henry VIII. This Company's position was not, however, established without some opposition, for the Dyers Company long and strenuously claimed to have the precedence. Peace was, however, restored during the Mayoralty of Sir William Boteler (1515), when the Dyers Company complied with an order of the Court of Aldermen and consented "lovingly and charitably to follow the Shearmen without any further strife or debate."

The recognised order of precedence among the twelve Great Companies is as follows—Mercers; Grocers; Drapers; Fishmongers; Goldsmiths; Skinners; Merchant Taylors; Haberdashers; Salters; Ironmongers; Vintners; and Clothworkers.

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* History of the Livery Companies. Vol. I, p. 101.

The Clothworkers' Company had its arms first granted in 1530 (22nd of Henry VIII), the crest and supporters being granted in 1587. They were confirmed in 1635, and are described as follows—

> "Sable, a chevron ermine between two habricks, in chief argent, and a thistle in base, or; crest a ram passant, or; supporters, two griffins, or; pellete. Motto—My Trust is in God alone."

It may interest you to hear the following information which was sent me by a friend, as regards the "habricks" or "habicks" as they have since been termed—

> " 'Shearmen' were craftsmen who sheared or faced the cloth, by cutting off the Nap (as is done now on our 'perpetuals' or cutting machines)."
>
> "They could only deal with about a yard at a time and the instruments on the coat of arms were used as hooks to hold the corners of the yard or so of cloth under immediate operation, much the same as drawing pins hold a sheet of drawing paper."

Such is a brief summary of the ancient history and of the modern activities of the Clothworkers' Company, and I may claim that it represents that of all the principal Gilds, who have done like work in educational, industrial, and philanthropic spheres. I hope you will be able to feel that the past history of the Livery Companies is a tale of effort on the part of the members to uphold and maintain the ancient traditions and honour of their respective Gilds, to further and promote the interests of the trade with which they are or have been associated, and at the same time, while not unmindful of the care of their poorer brethren, to benefit their generation. I think that to-day you will find these companies still retaining their ancient homes and some of their treasures, keeping abreast of, and adapting themselves to, changing circumstances, showing themselves alive to the spirit of the age, ever actuated by the desire to render public service, and devoting large sums out of their corporate income to charitable and benevolent purposes, for the "Profit and Commodity" of mankind.

A Meeting of the Section held on 7th March 1934, *at* 104 *Newgate Street, London; Mr. L. J. Mills in the chair.*

METHODS AND SYSTEMS FOR WATERPROOFING TEXTILE FABRICS

The lecturer, Mr. John Howard (Fellow), said that the object of his lecture was to put on record some of the experience gathered in the Stores Department of the India Office during his 30 years term of service. The climatic conditions of India were much more intense than in this country, and everything sent out had to bear not only the intense heat of the plains, but also, perhaps, the extreme cold of the North-West frontier. It was that difference in climatic conditions that ruined the biggest part of the goods used and caused the greatest number of complaints. The material sent out was mostly rubber-proofed single and double texture for cyclists' and motor drivers' clothing and ground sheets. There were also used canvases proofed and unproofed, for covers, tanks, chaguls, Cape-cart hoods, etc.

Proofing these materials, continued Mr. Howard, could be divided into three distinct classes. First, waterproofing by coating or covering the interstices of a fabric with a solid coating of material which was waterproof, as for example by a rubber coating. In his opinion this was undoubtedly the best system of waterproofing textiles. The second class was waterproofing by impregnation in which the best system, and the most effective, was by use of linseed oil or tar. The third class, which had not proved satisfactory, was what is known in this country as "showerproofing" by the use of wax plus acetate or formate of alumina.

The rubber system, said the lecturer, was certainly the most satisfactory system of proofing, but it was exceedingly difficult to get it done well. During the war the army was using a single texture fabric, but it was found by experience in India that if ground sheets of single texture were exposed wet to the sun it disintegrated the rubber; so it was decided to adopt double texture fabric. After many samples had been inspected it was decided to adopt a certain cloth. From this cloth a thousand sheets were sent out that were entirely satisfactory, but other sheets that were made and proofed on apparently the same system were not satisfactory. In the first case it was found that the rubber did not tear when the cloth tore, and these sheets lasted for three years, but the sheets where there was no elasticity in the rubber did not last twelve months. Chemically the two rubbers used were exactly the same and it was in the process of fixing the cloth on each side of the rubber that success or failure was achived. A great many complaints were received of motor-cyclists' jackets which always "went" in the bend of the elbow. It was found to be from the same cause, i.e. the rubber inside was so rigid that when the arms were bent it broke and cracked, thus allowing entry of damp.

Mr. Howard next referred to waterproofing by impregnation by linseed oil or tar. Though there was no doubt that was certainly the best method, it had the disadvantage that they dare not send linseed oil to India because it became liable in storage, to spontaneous combustion, and they dare not send anything impregnated with tar because the intense heat melted it. For these reasons another method was sought and finally they adopted the cuprammonium plus bitumen system. Fabrics so treated were sent out by the Government, for test, to 80 different stations in the British Empire under all sorts of climatic conditions and not one single complaint was received. This system of waterproofing heavy canvas had this advantage that the cuprammonium entered the fabric and made it rot-proof whilst the bitumen makes a surface proofing and together produce a solid water-tight material.

The lecturer next said he had to deal with wax and chemical proofing. Originally it had been adopted more as a preservative of canvas, but in his opinion its value was dependent almost entirely on the quality of the fabric. It was not satisfactory to wax or chemical proof a piece of inferior material. Another objection to chemical proofing was that it was apparently excessively liable to fungoid growth. That was why he preferred bitumen proofing.

The water-repellent or showerproofing system was Mr. Howard's next topic. He showed a showerproof garment which had been worn for some years and was still effective. He pointed out that the merit of that particular garment lay in its lining which was waterproof. He submitted that the finest waterproof garment in the world was the Irish frieze overcoat. Sheepskins were also extremely effective against rain. In conclusion he referred to the introduction of latex which was to play an important part in future water proofing.

In the discussion which followed, the Chairman and many members present, took part. The samples provided by Mr. Howard were examined and finally a very warm vote of thanks to the lecturer was carried unanimously.

Lancashire Section

Meeting at the Institute Headquarters, 16 St. Mary's Parsonage, Manchester, on Wednesday, 14th March 1934; Mr. T. E. Mitchell in the chair

THE THEORY AND PRACTICE OF CALICO PRINTING

This was the title of a paper delivered by Mr. H. A. Mason-Jones, and the following is an abstract of his typescript.

No hard and fast rules could be given for the production of prints, as each works evolved a procedure most suited to the conditions obtaining at the moment, and even these required to be modified from day to day. It was imperative for calico printing that the impurities in cotton goods should be removed, as far as practicable, and this was accomplished during the bleaching process, which the lecturer briefly described.

When mercerising was required, continued the lecturer, the operation might be performed either before, or after, bleaching. The dyeing process, which must next be considered, might be carried out either before or after printing, according to the particular style of work in hand. As the theoretical application of the various colour series would be dealt with under the actual printing process, which was merely localised dyeing, it was only necessary, at this stage, said Mr. Mason-Jones, to describe the general methods of dyeing, and this he did briefly.

Turning to the preparation of dyestuffs for printing purposes, the lecturer said that these were generally bought either in form of powder or paste. But even in the paste form, their consistency was much thicker than was required for the printing machine. Colour mixing had to be very carefully carried out, as many and varied printing faults might be attributed to incorrect or careless colour mixing. Consistency of the colour pastes had to be in accordance with the particular type and texture of the cloth being used, the style of design, and the character of engraving employed. Certain "thickeners", gums, starches, pastes, etc., were used to give the required firmness or density to the paste, and these "thickeners" varied not only according to the different colours and style of work, but also according to the reactions occurring between the colours, mordants, and pastes, when mixed together. "Thickeners" were of two distinct types, *viz.* those which, when they had served their purpose of thickening the colours, were subsequently removed from the fibres, and those which also served the purpose of fixing agents, and which, therefore, remained in the finished article.

The actual operation of printing, said Mr. Mason-Jones, might be carried out by one or other of several methods, and of which the following were these chiefly employed at the present time, *viz.*—

Hand Block Printing; where each separate colour required its own block manipulated by hand.

Perrotine Printing; which was a mechanical imitation of hand-block printing.

Screen Printing; in which the unvarnished portions of a fine silk screen allowed colour to be applied to the cloth lying on a table beneath the screen.

Machine Printing; which was the modern method of printing from engraved copper rollers and was unquestionably the ideal method of printing cloth in bulk. A development of the roller printing machine, and one that was adapted specially for printing handkerchiefs, sarries, and other bordered fabrics, allowed the printing rollers to move automatically out of gear, away from the cloth, and then into gear, for printing, at specified intervals, as required. The cloth to be printed passed between the engraved rollers and a large pressure bowl, and received from each of these rollers, in succession, its complement of colour whereby the design was completed. The pressure of the printing rollers against the large cylinder could be adjusted and adapted suitably to the type of fabric, character of pattern, and style of work in hand. Also the rollers were capable of slight adjustment in order to ensure perfect registering of the various colours.

Continuing, the lecturer pointed out that though the cloth, when passing through the printing machine, received a full impression of the design, yet, the different colours, as printed, very rarely bore more than a faint resemblance to those that appeared in the finished fabric; nor were the colours either fast or fixed in the cloth, at this stage. In fact, very frequently, they were not true colours at all, but merely basic materials or compounds that would, under suitable conditions mutually react and serve to precipitate upon the fibres an insoluble colour lake. Many other printed substances served the purpose either of attracting or resisting the colouring matter from a subsequent dyebath. For these reasons, various processes were now used for the development, fixation, and brightening of the colours, while subsequent processes served to remove the thickening agents, dye stains, and by-products of the preceding operations. All these operations are grouped together under the general term "After Processes", and consist of one or more of a series of operations indicated in the following list, Ageing; Steaming;

Dunging; Dyeing; Fixing; Raising; Cutting; Washing; Chroming; Soaping; Clearing; and Drying. Some of these processes were described briefly as follows—

Ageing was the exposure of the printed fabric to the action of warm, moist air, or steam, in a special room or chamber constructed for that purpose. Ageing provided the conditions necessary for the oxidation or reduction of certain colours that required to be fixed upon the fibres by this means.

Steaming was a similar, but more prolonged, process, where again, temperature, humidity, and rate of travel varied to suit the type of work in hand.

Dunging was an operation performed on goods printed with a mordant, to be subsequently dyed. The process of dunging was effected by passing the cloth either through a solution of cow-dung or some other suitable synthetic dunging agent. The effect of this process was to complete the fixing of the mordant; to render insoluble any decomposed mordant, thus preventing unfixed mordant from becoming attached to unprinted parts of the fabric; and to remove the thickening agent used in the mixing of the printing paste.

Fixing was the name given to a further operation which completed the fixation of colour or mordant previously only partially fixed by a preceding operation, and was effected by passing the printed or mordanted cloth through solutions which served either to precipitate the mordant in the form of an insoluble oxide, hydroxide, or other salt, or else to increase the complexity, and hence the insolubility, of a colour lake.

Raising or *Developing* was effected by passing the printed goods through a liquor which combined with the substances on the printed portions of the fabric. The result of this combination was the appearance of colour on those printed portions.

Chroming was in operation in which a solution of a chrome salt was used to brighten certain types of colours already printed and fixed upon the fabric.

Clearing, as the term implied was a final process which consisted of passing the cloth through a weak bleaching solution in order to remove the stained appearance of the "whites".

The lecturer next made reference to the technical application of the various dyestuffs to the fabric. He preceded his remarks on this subject by a brief reference to mordants in which he said that whilst there were certain dyestuffs for which the fibre had a natural affinity, yet, the majority of dyestuffs could not be fixed upon the fibre in a permanent form without some special technical process, or by the addition of some other substance either to the dyestuff, or to the cloth. Other dyestuffs could only be utilised when the dyes were combined with a suitable metallic base to precipitate a coloured lake and to fix this precipitate on the fibre. These substances, which possessed the property of forming insoluble lakes by reacting with dyestuffs or colouring matters, were called mordants. Certain dyestuffs would combine with several such mordants separately to develop a variety of different hues, whilst other dyestuffs, although they would combine with several mordants, yielded only the one hue, in slightly varying shades. The range of mordants included many substances of varying characteristics. Acids, alkalies, neutral or basic salts, and hydroxides, served the purpose of mordants. After the printing processes had been completed, the mordant itself became an essential part of the colour lake appearing on the fibre. Mordants were applied to the cloth either by padding, or by printing the substances, in solution, directly on to the cloth: or they might be mixed with the colour, and both applied at the one operation of printing.

The dyestuffs employed, said the lecturer, were grouped together in ranges or series according to their general characteristics, and he made a few observations on each of the following colour series before dealing with their technical application.

The *Direct Cotton Dyes*, which dyed cotton without the use of mordants.

The *Basic Dyestuffs* used chiefly where brightness was of primary importance.

The *Mordant Colours* were applied with a mordant. With few exceptions, a chrome mordant was used, for which reason, this range was often styled "chrome colours".

Azoic Dyestuffs, also described as "developed" and "ice colours", were not applied as colours, but were developed upon the fibres.

The *Sulphur Colour* range provided some excellent fast dyes; particularly in black.

Albumen Colours, also termed "pigment colours" were bright and reasonably fast, except to rubbing.

The *Vat Colours* probably constituted the most important type of dyestuffs in use to-day. They comprised a full range of hues, and the general standard of brightness and fastness was excellent.

Dealing with methods of applying colours, Mr. Mason-Jones said there was the direct or steam style, where the colours were fixed by a steaming process; the developed style, where the colours were actually made or developed on the fibre; and the "resist" and "discharge" styles, where a uniform ground shade, applied by dyeing, was either resisted, during dyeing, or else discharged, subsequent to that process. In the direct or steam style, the colours were printed on to the fabric along with the necessary assistants or mordants, the fabric being afterwards exposed to the action of steam suitably regulated as regards temperature and humidity, and for a period determined by the requirements of the colours employed. The direct cotton colours needed no assistants, mordants, or special processes. The other colour series mentioned were briefly described as their mode of application varied.

Having dealt with the methods of producing the direct style of prints, wherein the colours were printed on to white cloth and fixed thereon to give a coloured pattern, the lecturer pointed out that in the dress goods trade, bright colours were often required to stand out against a dark back-ground. This effect could be produced by either of two alternative methods known as "the discharge style" and the "resist style", respectively.

In the "discharge" style of printing, he continued, the cloth was first dyed after the completion of all preparatory operations, thus giving a uniform shade throughout the piece of cloth. The dyestuffs used for this ground-shade were of such a nature that they might readily be discharged or destroyed by some powerful reducing agent, and all except the fastest colours might be used for this purpose. Where merely a plain white pattern was required on a coloured ground, the discharging agent was thickened and printed on to the dyed material. During the subsequent ageing, the dyestuff was reduced, and a white pattern left in its place. To print a coloured pattern, a discharging agent was mixed with the printing paste containing the colour, and the whole was printed at one and the same time. The ground, or dyestuff, was discharged from the cloth during the steaming and the colouring matter contained in the printing paste immediately becomes attached to the fibre, thus producing, in a single operation, a coloured pattern on a dyed ground.

In the converse or "resist" style of printing, said the lecturer, the resisting agent was first printed on to a bleached cloth either alone or in conjunction with a colour paste, and the print was fixed. Subsequently, upon dyeing, the dyestuff was resisted by the printed portion of the cloth, and again a white and/or colour pattern was produced on a dyed groundwork.

Mr. Mason-Jones in conclusion referred to the final process of finishing which, he said, was dependent more upon the manual skill and dexterity of the operative, as well as the mechanical processing, than upon the use of mineral or chemical substances, although, of course, some of these were employed for the purpose of imparting to the cloth certain desired textural effects according to the particular class of fabrics and the uses for which they are intended. The finishing processes made cloth more presentable for the market both in appearance and "handle". He gave a brief description of the various finishing processes.

The Chairman (Mr. T. E. Mitchell) said the lecturer had provided an interesting survey of the processes involved in the printing of fabrics. In addition to the processes, there was a great field of craftsmanship before printing began. Printed fabrics of to-day represented a really wonderful achievement, both on the chemical and the engineering sides.

Questions were asked and, in reply, Mr. Mason-Jones said there was still a sound demand for hand-block printed materials, though, on account of cost, the process was more or less confined to the more expensive cloths.

On the motion of Mr. F. D. Farrow, seconded by Mr. L. N. R. Sheret, a hearty vote of thanks was accorded to Mr. Mason-Jones.

NOTES AND NOTICES

NEXT ANNUAL CONFERENCE

Arrangements are now concluded for the holding of the 1935 Conference of our Institute at Ilkley, the Yorkshire health resort, in the latter part of Whit-week. The headquarters will be the Wells House Hotel, which will afford ample accommodation for all meetings and social events on the premises. The official period of the Conference will be from the Wednesday afternoon to the Friday afternoon inclusive (12th to 14th June), and Members will be able to extend their period of stay on the special terms applicable to the Conference period. The general subject of the Conference Papers will be that of "Conversion of Fibres into Finished Yarns" and papers will relate principally to factors affecting the production and quality of yarns. Arising out of the programmes of papers at the Institute's Annual Conferences, it has been found that many papers contributed can be suitably presented after at the Section meetings. Several instances have occurred, during the current winter session programmes, of continuance of discussion by means of selection of Conference papers with appropriate modification or amplification. The Yorkshire Section, for instance, has arranged for a paper by Professor W. Davis on "The Growing Importance of Warp-knitted Fabrics", to be presented at Bradford on the evening of 31st January next, which represents a development of the subject dealt with by the author at the 1934 Conference.

Lancashire Section of the Institute

Although it was felt that last year's effort on the part of the Lancashire Section Committee to introduce a social event into their programme was perhaps a little on the ambitious side, a dinner-dance being promoted, yet it was unanimously agreed to include a similar event in the programme for the current session. On the first occasion, no little difficulty was experienced in securing an adequate response, but eleventh-hour endeavour on the part of several members of the Committee secured a really satisfactory attendance. This year, the courage involved in repetition of the fixture was fully rewarded, the response being both prompt and ample. The dinner-dance took place at the Grand Hotel, Manchester, on the evening of Saturday, 15th December, and the event was highly successful.

Institute Annual Competitions

The distribution of prizes in connection with the 1934 Competitions of the Institute, which took place at Headquarters, Manchester, on Saturday, 8th December, proved an exceptionally interesting event. The attendance was larger than usual and the President (Sir Thomas Robinson, K.B.E.) kindly occupied the chair. The exhibits formed a highly creditable collection of the work of students. The event was favoured by the attendance of members of the National Society of Art Masters (North-Western District). The president of the National Society is Mr. W. M. Whitehead, J.P., A.R.C.A., Principal of the Burnley Municipal School of Arts and Crafts, and, in presenting the prizes to the successful competitors in the Institute's Competitions, he contributed an appropriate and useful address, which is briefly recorded in the report of the proceedings in another part of this issue. Subsequent to the prize distribution, the members of the Society of Art Masters held a meeting at which a short paper was contributed by Mr. J. D. Athey, on the subject of the Institute's competitions and design in relation to textile fabrics. In the course of the paper, the difference between design for woven and for the printed fabric was emphasised. It was urged that there appeared to be room for extended training on the part of students in two directions—the selected art-school student to proceed to more advanced technical studies, and the selected technical student to more advanced art training. In both connections, it was suggested, there was room for extended training of students selected by reason of their ascertained aptitude and promise.

Textile Institute Diplomas

Election to Fellowships and Associateship have been completed as follows since the appearance of the previous list (October issue of this Journal)—

FELLOWSHIP

STARKIE, Jethro (Nelson)

ASSOCIATESHIP

HAYES, Arnold Ainsworth (Bolton)
SNOWDEN, Duncan Campbell (Galashiels)

Institute Membership

At the December meeting of the Council, the following were elected to Membership of the Institute—*Ordinary:* J. B. Dickson, A. G. Spalding & Bros., Chicopee, Mass., U.S.A. (Director of Research); M. S. Hodgson, 6 Glenview Terrace, Murdieston Street, Greenock, Scotland (Apprentice Dyer, W. McConnel & Co. Ltd., Bridgeton); A. Howarth, 37 Chief Street, Oldham (Mill Foreman of Winding Department); J. C. H. Hurd, "Laneham", Kirkland Road, Leicester (Knitting Machine Designer, etc.); J. E. Irvine, 49 Greenlaw Avenue, Paisley (Manager, Dyeing and Bleaching); H. Jackson, 105 Valley Road, Bredbury, near Stockport (Cotton Doubling Mill); D. S. Takalkar, c/o The University, Leeds 2 (Student); A. Taylor, Technical Institute, Haywra Crescent, Harrogate (Full-time Assistant Master); S. Whiteley, 22 Devon Street, Halifax (Instructor in Weaving); W. G. Byerley, 113 Washington Street, Girlington, Bradford (on Senior Staff of Wool Industries Research Association, Leeds); F. N. Chell, Ball Haye Road, Leek, Staffs. (Student, Nottingham University College). *Junior:* A. Mathewson, 12 Geoffrey Avenue, Leek, Staffs. (Department Manager for Hosiery Manufacturers); J. K. Srivastava, College of Technology, Manchester (Student). G. Williams, 66 Higher Swan Lane, Great Lever, Bolton (Assistant Comber Overlooker, Swan Lane Spinning Co.). *Life Membership:* P. H. Bhutta, c/o D. C. Vora, Madanji Mohanji Mala, Dady Sheth Agiari Lane, Bombay 2, India (Carding Master;

REVIEWS

Proceedings of the 38th Annual Convention of the American Cotton Manufacturers Association. Published by the Association at Charlotte, N.C., U.S.A. (119 pp. and Table of Contents.)

The Convention reported in this volume was held at Charleston, South Carolina, in April of this year. The report contains two addresses of note; firstly, that by the retiring President of the Association, T. M. Marchant, who dealt with the position of the cotton textile industry in the States and who furnished a number of tables dealing with Employment, Wages, Cost of Living, etc. in the industry. He referred in the main to the National Recovery Administration but also made reference to legislation generally, and particularly to the Agricultural Adjustment Act. He also surveyed the activities of the Association in relation to the Economic conditions prevailing. The second outstanding address was that by G. A. Sloan, President of the Cotton-Textile Institute, who dealt with the incidence and operation of the National Recovery Act and more particularly in regard to its application in the cotton industry. The report of his address is illustrated with graphs of hourly wage rates, weekly earnings, employment, and cotton consumption over the period 1929-1934.

Official Chemical Appointments. Eighth edition. Compiled and issued by the Institute of Chemistry of Great Britain and Ireland at 30 Russell Square, London W.C.1. 1934.

The object of this publication, as stated in the introduction, is to provide a list of official appointments which are, or may be held, by chemists. The scheme was adopted in 1906 and in this edition it has been adhered to; corrections have been made as well as many additions. The appointments recorded are divided into two main groups—I, Appointments in Great Britain and Ireland, and II, Appointments abroad. It should be invaluable to those who are contemplating entry into the profession as well as to those already embarked upon a career in chemistry. T.

The Definition of Textile Filaments and Yarns. By G. Strobino. Published by Associazione Fascista dell'Industria Laniera Italiana. (85 pp.)

This booklet covers a wide range, giving first in elementary fashion the definitions of the term "filament" or "fibre" as applied to textiles. After outlining the different methods of measurement of fibre thickness, the author begins a systematic study, firstly of metallic wires, secondly of textile filaments, and thirdly of the fundamental issues underlying the classification and nomenclature of all kinds of wire or thread. Having defined these quantities, he proceeds to relate them to strength, thickness and general configuration of yarns, ropes and cables. The booklet is illustrated by both mathematical and graphical argument in support of the conclusions. W.

Linen Industry Research Association: Library Catalogue 1920-1933. Published by the Association at Lambeg, N. Ireland. (77 pp. with Name and Subject Indexes. Price to non-members, 10s. net.)

This little volume should have a wider general appeal than, perhaps appears at first sight. The Library of the Association is associated with the National Central Library, London, and its contents are available to anybody or persons interested in the subjects covered. Publications may be borrowed (15 days) or consulted in the Library. On these grounds, then, a much wider field of potential and actual users will be interested; hence the catalogue has been made available also. The volume is also interesting from the point of view of those whose task it sometimes is to catalogue and classify information. The compiler may be definitely congratulated in this case because, as soon as the system of classification adopted (*vide* pages 3 and 4) has been grasped, search for information is readily made. One or two minor criticisms might be made as to the grouping in certain parts of the classification. But as it is always much easier to criticise than to construct it will suffice to say that the writer would, and does, solve similar problems in classification somewhat differently. T.

World List of Scientific Periodicals. Published in the years 1900-1933. Oxford University Press. 1934. (Price £3 3s.)

The first edition of this work appeared (in two volumes) in 1925 and 1927. Since then errors and omissions have been recorded and of course numerous new periodicals have made an appearance. Thus the second edition became necessary and through the generous gift of £1,000 from the Royal Society of London, its production was made possible. Superlatives in commendation of this stupendous task—it lists 24,029 scientific and technical publications—do not seem adequate. It must suffice to say that it is in constant use and provides information and aid that can be obtained nowhere else. T.

Cotton Year Book, 1934. Published by *The Textile Mercury*, 41 Spring Gardens, Manchester. (Price 7s. 6d. net.)

Twenty-nine years of issue for a year book seem to indicate that it is in demand. There would appear to be ample justification for such an assumption and the volume now noted will find its way on to the reference shelf to provide that handy source of information it has proved to be already. T.

The "Textile Manufacturer" Year Book, 1934. Published by Emmott & Co. Ltd., 31 King Street West, Manchester 3. (Price in Great Britain, 3s. 6d. net.)

The Editor of this year book makes a praiseworthy effort to deal with the fact that, with an accelerating body of knowledge in textile technology, text-books are actually out of date on publication. New articles are included, and old ones rightly excluded, reflecting and describing progress in methods, equipment, and outlook. Such a course ensures the real value of the volume in hand. T.

"The Textile Recorder" Year Book, 1934. Published by the Harlequin Press Co. Ltd., Old Colony House, Manchester 2. (Price 7s. 6d. net.)

The appearance of this volume affords the opportunity to state that the publication, once the property of John Heywood Ltd., has now passed into other hands. It is a matter of satisfaction that it has not been allowed to lapse. The book claims to be "a textile library in brief" and so long as it is kept up to date it will continue to serve a good and useful purpose. With the intention, therefore, of making a suggestion, which is what the Editor asks for, we venture the criticism that the list of contributors contains names of experts who have passed away, in some instances, years ago. Admirable though they were, probably their contributions should now be revised. T.

"The Knitting Trades Directory for 1934." Published by the Harlequin Press Co. Ltd., Old Colony House, Manchester 2. (Price 2s. 6d. net.)

Here is another "John Heywood" publication now produced by the Harlequin Press, and definitely improved in more than one direction. A headline to each page facilitates reference to its various sections and the index to the "Buyer's Guide" has been put immediately preceding the pages bearing the guide. It is not exaggeration to say that this is a very useful publication. T.

Silk and Rayon Directory and Buyers' Guide of Great Britain. Published by the Harlequin Press Co. Ltd., Old Colony House, Manchester 2. (Price 21s. net.)

One is tempted to speculate, on reading the List of Towns and Villages with which this directory commences, as to what names and how many would have been in the list had it been compiled in 1834. Aberdeen, Bacup, Colchester, Low Moor, Silvertown, Tean, Winton and Yeadon indicate the widespread area covered by the silk and rayon industries. All of which is definitely evidence of the need for direction and information in regard to the many firms and productions concerned. The reasons for annual production are additions, corrections, and alterations; these never cease and so one may welcome the latest addition to the reference shelf, albeit the price seems rather on the high side. T.

"The Lancashire Textile Industry—The Cotton Spinners' and Manufacturers' Directory for Lancashire." Published by John Worrall Ltd., Oldham. (Price 15s. post free; abroad 17s. net.)

Two things in particular impress themselves on one's mind in connection with this new volume. It is the 50th issue and it is produced, as were its predecessors, of course, in Oldham. Could any testimony be stronger to Lancashire pertinacity? "Look for it in Worrall's" must be on the lips of any, and every, textile man. These directories—it is one of an invaluable series—present up-to-date information as to the firms and productions of the cotton trade. This particular issue—being number 50—has, justly been the subject of general congratulation which can be heartily endorsed, even though its claim to appreciation lies in the steadily pursued policy of issuing an accurate and up-to-date directory and not in temporary supplements. T.

GENERAL ITEMS AND REPORTS

SHRINKAGE IN SILK AND RAYON BROAD GOODS

The National Federation of Textiles of New York, U.S.A., has for some time been concerned with the determination of shrinkage and the best method of conducting tests. Recently a brief account of the preliminary work was issued together with a "Tentative Standard", which is here reproduced as being of interest to all concerned.

History of the Work

On 8th August 1933, a preliminary report was issued to members of a Committee working with the Silk Association of America, Inc. This report gave the results done on two samples by seven laboratories, each laboratory using the method which it thought best adapted for its own particular work. The results showed very poor checks and a study indicated that the manner of pressing after washing was the cause for considerable irregularity.

A second series of samples was sent out, this time to three laboratories, to check results obtained by the use of a flat-plate ironer as a means of pressing. The results were very gratifying but still showed differences considerably greater than 2 per cent. These tests were reported in December 1933.

The failure of the last results to check was thought to be due to the non-uniformity of hand washing, so a study of this problem was made at the laboratory of the United States Testing Co., Inc., and the conclusions pointed very definitely to the use of the Launder-Ometer, or similar apparatus. On 17th January 1934, a report was issued giving the data obtained from these latter experiments.

It might be mentioned that, theoretically, a standard method for shrinkage and a standard method for dye fastness to washing, would call for an identical treatment, and both tests could be made on the same sample. This was virtually found to be a fact, as each of these tests, developed entirely independently of each other, called for a twenty-minute treatment in the Launder-Ometer at 100° Fahrenheit, and under almost identical conditions. This was considered as substantial evidence supporting the correctness of both methods offered as tentative standards.

New Data—Series IV

Below will be found the results from Series IV, six samples sent to five representative laboratories. It will be observed that the samples fairly represent the silk and rayon fabrics in general use.

RESULTS OF SHRINKAGE TESTS ON SAMPLES OF SERIES IV

Samples 1 Weighted Georgette
2 Rayon Canton Crêpe
3 Rayon Mossy Crêpe
4 Acetate Taffeta
5 Weighted Canton Crêpe
6 Pure Dye Canton Crêpe

Sample Number	PERCENTAGE SHRINKAGE Bureau of Standards	Good Housekeeping Institute	Lux Laboratories	Sears, Roebuck & Co.	United States Testing Co.	Average
1 WARP						
Max.	7·8	8·3	8·0	7·8	7·7	
Min.	6·1	7·9	7·0	6·5	7·0	
Ave.	6·9	8·1	7·5	7·1	7·3	7·4
FILLING						
Max.	10·0	12·0	13·0	9·7	10·2	
Min.	6·6	7·9	5·0	7·2	7·8	
Ave.	7·9	10·0	9·3	8·3	9·2	8·9
2 WARP						
Max.	7·0	6·9	7·0	8·4	5·0	
Min.	6·2	5·3	4·0	5·7	4·5	
Ave.	6·6	6·3	5·5	7·1	4·8	6·1
FILLING						
Max.	17·0	16·6	17·0	16·7	16·8	
Min.	14·9	13·1	15·0	15·3	15·3	
Ave.	15·9	14·9	15·8	15·9	16·2	15·7

RESULTS, etc.—*continued*

PERCENTAGE SHRINKAGE

Sample Number	Bureau of Standards	Good Housekeeping Institute	Lux Laboratories	Sears, Roebuck & Co.	United States Testing Co.	Average
3 WARP						
Max.	22·7	22·8	23·0	23·0	24·8	
Min.	21·1	20·8	22·0	20·7	23·0	
Ave.	22·2	21·8	22·3	22·2	24·2	22·5
FILLING						
Max.	19·9	19·8	23·0	21·7	23·3	
Min.	16·8	17·5	20·0	19·5	19·0	
Ave.	18·0	18·3	21·0	20·3	20·8	19·7
4 WARP						
Max.	3·1	2·0	3·0	3·3	3·0	
Min.	2·3	1·5	2·0	2·3	1·8	
Ave.	2·7	1·8	2·3	2·6	2·5	2·4
FILLING						
Max.	0·6	-0·3	0·0	-0·4	-0·2	
Min.	-0·2	-1·2	-1·0	-1·1	-1·2	
Ave.	0·1	-0·8	-0·5	-0·8	-0·6	-0·5
5 WARP						
Max.	2·3	2·4	2·0	3·2	2·5	
Min.	1·2	2·0	1·0	2·1	1·5	
Ave.	1·7	2·1	1·5	2·6	2·1	2·0
FILLING						
Max.	10·2	9·9	10·0	11·8	11·5	
Min.	8·6	9·1	9·0	10·2	10·5	
Ave.	9·6	9·5	9·8	10·9	11·1	10·2
6 WARP						
Max.	8·6	7·5	8·0	7·8	8·2	
Min.	6·3	7·5	6·0	6·5	7·8	
Ave.	7·4	7·5	7·0	7·2	8·0	7·4
FILLING						
Max.	12·9	10·7	13·0	13·9	16·2	
Min.	10·0	9·3	12·0	12·2	13·5	
Ave.	12·1	10·0	12·8	13·2	14·9	12·6

— Signifies a stretch

Discussion of the Results

The results as a whole show very good agreement, considering that 1% corresponds to 1/10th of an inch. They are certainly sufficiently close for all practical purposes.

Your attention is called to the following—

(1) The samples were not prepared with more than ordinary care, as it was desired to simulate as nearly as possible the technique of an ordinary laboratorian.

(2) There were a few samples which were thrown out, due to very irregular results. These appeared to be in the nature of accidents and no reason is known for this condition.

(3) It is essential that the samples be measured within 24 hours after running the test. It has been definitely proven that considerable change takes place from day to day in the samples after the test.

(4) The final method specifies measuring at the ends and at the middle. It was found that this method differed less than 1·0% from measuring at the middle and 1 inch from each end, so for the sake of uniformity (cotton shrinkage tests are measured at the ends), it was thought best to change to the method indicated.

Unless there are valid objections to some features of this method as proposed, it will be shortly offered to the American Society for Testing Materials for inclusion in their publications as a tentative method.

Our most sincere thanks are tendered to all of those whose co-operation made the successful conclusion of this work possible.

PROPOSED TENTATIVE STANDARD METHOD FOR THE DETERMINATION OF SHRINKAGE IN SILK AND RAYON BROAD GOODS

1—Sample

The area tested shall be 10 by 10 inches, with a one-inch margin, each test sample to be cut individually to a 12 by 12 dimension.

No part of the area measured for test shall be taken from within 2 inches from the selvedge.

The part measured shall be outlined by marking with indelible ink or by a thread sewn into the cloth.

2—Method of Washing

The sample shall be treated in the Launder-Ometer, in 300 cc. of a ½% neutral soap solution, for 15 minutes at a temperature of 100° Fahrenheit. Remove from the jar and rinse by dipping in water at 100° Fahrenheit (do not squeeze). Place in the jar with 300 cc. of fresh water and rinse for 5 minutes at 100° Fahrenheit. Remove from the machine and without squeezing lay on a flat tray, or other flat surface, and keep in a horizontal position until the great excess of water has evaporated. Wrinkles can be removed by laying the sample on a stone slab and pressing with the palm of the hand.

3—Method of Pressing

The samples shall be pressed while still appreciably damp in a flat press (G. E. Flatplate Ironer or similar is satisfactory) at a temperature between 275° and 300° F., being careful to press only long enough to remove the moisture.

4—**Condition** two hours or longer at ordinary atmospheric conditions.

5—**Measure** each side of each piece at three places—

1—At the middle
2 and 3—At each end
Average all measurements for each dimension.

6—**Report** shrinkage in warp and filling in percentage of original 10-inch dimension.

(Signed) H. A. Mereness, *Director*
Technical Bureau

WAGES AND UNEMPLOYMENT IN THE BOMBAY COTTON TEXTILE INDUSTRY

Report of a Departmental Inquiry conducted by the Labour Office of the Bombay Presidency. (220 pp. Price Re. 1 As. 3, or 2s.)

In the P.E.P. report on the British Cotton Industry* in the section dealing with the cotton industry in other countries, it is stated that "at the present time mills are springing up in other centres than Bombay and in many quarters it is believed that the Bombay industry will decline". This report bears directly on the point, and should be read in illumination thereof. The inquiry was instigated by the Bombay government and entrusted to the Labour Office to carry out. The report is in six parts. The first is introductory in character and covers the textile industry in the Presidency, generally. Part II deals specifically with Bombay centre; Part III with Ahmedabad; Part IV with Sholapur and Part V with other centres. In Part VI are given the conclusions and the whole are supplemented by two tabular statements, eight tables and nine appendices. The introduction states "Tables illustrating the progress or decline of the industry in the various centres as reflected in the number of working mills and the number of operatives employed as well as according to production are given in this chapter. These tables, which cover the period from 1926 to 1934, are of importance. They reveal several striking features. It will be observed how in the past eight years the centre of gravity of the textile industry in the Bombay Presidency has tended to shift from Bombay to Ahmedabad and other parts of the Presidency. This is apparent, not only as regards the number of operatives employed in them. In Bombay City the unit is very much larger than elsewhere, except in Sholapur. In Ahmedabad, for example, the average number of persons employed in a mill is about a thousand, whereas in Bombay it is nearly double that number.

J. Text. Inst.*, 1934, **25, P367.

In 1926 Bombay had 78 mills working, employing on an average over 148,000 operatives daily. In Ahmedabad, during the same year, nearly 56,000 persons were employed and in other centres over 41,000, making a total for centres outside Bombay of nearly 97,000 or over 51,000 fewer than in Bombay. The number of mills working in the other centres was 84.

In 1933 the number of working mills in Bombay had dropped to 66, employing about 105,000 hands. The figure for Ahmedabad had risen to 75 mills employing over 82,000 hands and in other centres the number of mills was 32 employing 45,500 hands. That is to say, the number of cotton mill workers outside Bombay was actually 22,000 more than in Bombay City, as compared with 51,000 in favour of Bombay in 1926. In the same period the number of working mills in Bombay had fallen from 78 to 66. In Ahmedabad the increase was from 59 to 75 and in other centres from 25 to 32. That is to say, Bombay City had 12 fewer mills working. Ahmedabad had 16 more and other centres 7 more.

In March 1934, when this inquiry was started, Bombay's position had worsened still further. Only 55 mills employing 95,637 hands were working, as compared with 79 in Ahmedabad, employing 80,866, and 32 in other countries employing 42,216. In other words, 27,455 more people were working in cotton mills outside Bombay City than in Bombay City as compared with the 51,386 difference in favour of Bombay in 1926.

This quotation seems to indicate that the P.E.P. statement has reasonable foundation. T.

THE TRAINING OF MEN FOR THE TEXTILE INDUSTRY

Published by the Textile Foundation, Washington, D.C., U.S.A.

This publication is described by its author, Frederick M. Feiker, as an "inquiry into the specialised education for the training of men for the textile industry". It was undertaken at the request of the Board of Directors of the Textile Foundation who appointed a supervisory Committee to direct the inquiry. It was desired to secure a contribution to the answer to the questions—What types of trained men are needed for the textile industry? What are the requirements for their education? How do the present textile schools fulfill these needs and what improvements can be suggested? Mr. Feiker was appointed to conduct the survey and spent some seven months in the task. His report was endorsed by the special Committee directing the work which urges its careful study and adoption.

It is divided into eight sections as follows—Section I, General Findings; II, Opportunities for Trained Men in the Textile Industries; III, Trends in the Industry that Mould Textile Education; IV, Genealogy and General Background of Textile Schools; V, Matching Educational Objectives with Present Trends; VI, The Development of Courses to meet Educational Objectives; VII, Suggestions on Teaching Specific Subjects; and VIII, General Notes and Comments. The Report makes very definite and very interesting recommendations, reproduced below. Read in conjunction with the Report on the British Cotton Industry by P.E.P., recently reviewed in this *Journal**, these recommendations are particularly noteworthy as not only do they indicate the similarity of the position in the United States textile industry, but advocate educational reforms designed to facilitate similar remedies.

The Report reads—On the basis of the general background of the present educational facilities of the textile industry and in co-operation with the leaders in education and the leaders of the industry, the report recommends a series of educational programs, as follows—

A—**The establishment of five types of training for men in the textile industry. It is not assumed that all these types of training shall be provided by each of the present textile schools or that any of the present textile schools will find it desirable to undertake all these suggestions. They are presented with the idea that during the next five years an articulated educational plan can be developed for the textile industry, which will furnish men to meet the trends in the industry.**

1—Vocational—evening or day schools, curricula arranged, for one, two or three year certificate courses.

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*J. Text. Inst., 1934, **25**, P367.

2—Courses in textile mill management and production methods—a development of the present textile manufacturing courses leading to a degree after four years.

3—A four-year degree course in chemistry and dyeing to be developed on the basis of the present courses with that name by adding the management and control viewpoint.

4—A four-year degree course needing special development and complete reconsideration for men entering fields of merchandising and marketing.

5—Post-graduate training for textile school graduates in the special fields of industrial management, the research problems in chemistry and physics, and in the general marketing and sales phases of the textile business.

This is a field for graduate specialisation either in present schools where adequate facilities and staff are available or in general engineering, agricultural or business schools depending upon the subject.

B—Specific suggestions and subjects on remaking present textile manufacturing courses into textile manufacturing management courses.

C—A plan and specific proposal to simplify, co-ordinate, and standardise terminology, subjects and teaching materials of the general vocational part of the curricula called in this report "Textile Technique", with the object of gaining time for the presentation of other subjects.

D—Definite suggestions for teaching English, Economics, Marketing, Physics, an Engineering subjects, resulting from interviews with instructors in present textil schools, and with specialists in other universities and colleges.

E—The development and organisation of a proposed one-year course in Textile Technique for graduates of general engineering or arts courses in other colleges, so that they may quickly gain a specialised knowledge of the textile industry

F—A proposal for co-operative courses as a method for training men in textile m management in localities in which the mill practice and the school theory can be co-ordinated.

G—A proposal for the advanced training of a small number of men selected from graduates of degree courses of textile schools, whose records give promise of their capabilities in such special fields as physical and chemical research into fibres, advanced engineering work, industrial management or merchandising and marketing. It is proposed that these men be given the opportunity to take advantage of the highly specialised training available in these fields.

H—A proposal to hold annual meetings of the directors of the schools to foster anc promote the recommendations of this report.

I—The establishment of a follow-through plan divided into two parts—

1—A committee of directors and teachers on textile education objectives to report annually on progress made in carrying out the recommendations of this report.

2—A committee or a group of committees of textile instructors to counsel and advise, with a general staff consultant on three propositions—(*a*) The simplification and standardisation of the courses in Textile Technique, (*b*) the development of teaching materials and teaching methods in courses in applied economics, merchandising and marketing, and related business subjects, (*c*) the development of present textile manufacturing and chemical engineering courses.

There can be little doubt that this Report will be read with interest by all concerned with Textile Technical education in this country. T.

A MECCANO LOOM

There appears to be no limit to the constructions possible from Meccano parts. We have received a leaflet describing the construction of a model loom which, apart from its general interest, might open up new ideas to students and inventors. The model is constructed entirely of Meccano parts, and all movements are brought into play by means of a crank handle. A specimen of material woven on such a model loom has been received and though somewhat open in character has creditable selvedges and is not unpleasing in appearance. The ingenuity of the designer of this model is noteworthy.

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TRANSACTIONS AND INDEX

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TRANSACTIONS

1—THE FOUNDATIONS OF YARN-STRENGTH AND YARN-EXTENSION

PART V—THE PREDICTION OF THE SPINNING VALUE OF A COTTON FROM ITS FIBRE-PROPERTIES

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SUMMARY

The present paper deals with the problem of predicting the spinning value of a cotton from its fibre-properties. Previous work is discussed, particularly certain suggested relationships between spinning value and staple length alone or in conjunction with fibre-strength, and also between spinning value and fibre-weight; reference is also made to two other suggested methods of attacking the problem on quite different lines.

Criteria for judging spinning value are discussed, and the criterion finally adopted is the highest standard warp count, i.e. the highest count that can be spun from the cotton with standard twist to give a specified standard strength.

The tests at the Technological Laboratory are described for (1) spinning value, and the following fibre-properties—(2) length, (3) weight per inch, (4) ribbon-width, (5) strength, (6) convolutions, (7) rigidity, and (8) clinging-power. The results are given for two series: Series I, in which properties (1) to (7) were determined for 95 samples, and Series II, in which properties (1) to (8) were determined for 45 samples of Indian cottons.

From these results the attempt has been made to derive prediction formulæ for spinning value in terms of the fibre-properties, by means of the method of correlation. This method is briefly explained, together with some of its limitations. It is found that the total correlation coefficient is 0·87 for fibre-length and spinning value, and −0·75 for fibre-weight per inch and spinning value; the partial correlation coefficient of fifth order for the Series I samples is 0·70 for fibre-length and spinning value, and −0·36 for fibre-weight per inch and spinning value. From these results it is clear that the spinning value of Indian cottons is much more accurately assessable from the fibre-length than from the fibre-weight.

The accuracy of the prediction formulæ has been tested by comparing the actual spinning values with those calculated from the fibre-properties by the aid of the formulæ. Using the prediction formula based on fibre-length alone, the difference between actual and predicted spinning values is not greater than 20% in 69% of the cases; the corresponding percentages of cases for other prediction formulæ are 53% for fibre-weight alone, 76% for fibre-length and fibre-weight together, with no better result when either fibre-strength or ribbon-width is also included; and only 80% when all six properties are included. As the prediction-formula based on six fibre-properties is thus hardly any more accurate than the prediction-formula based on only the two properties of fibre-length and fibre-weight, it is concluded that the greater labour entailed in determining either the ribbon-width, strength, convolutions, or rigidity, is not worth while except for some special reason.

Finally, various anomalies between the actual and predicted spinning values are discussed, and a number of reasons advanced to explain them, and to indicate the lines along which future research might profitably be directed.

Appendix I gives a detailed description of the method of simple and multiple correlation used in obtaining the prediction formulæ, and the formulæ employed in making the necessary calculations; the method of making these calculations is explained. Many prediction formulæ are given, both simple and multiple, and

the degree of significance to be attached to the constants in these formulæ is also indicated in a number of cases. Two other methods, used as checks, for determining the constants of the prediction formulæ, are also briefly described. A note is given on the coefficient of multiple correlation, measuring the correlation between spinning value and all the fibre-properties combined, and having a value for the Series I samples of 0·93, from which it appears that 86·5% of the variation of spinning value is accounted for mathematically by the six fibre-properties, leaving 13·5% to be accounted for otherwise.

Appendix II gives a description of a short method for revising the total correlation coefficients to include further results as they become available in successive seasons.

Appendix III consists of tables of experimental results.

Appendix IV consists of tables showing how actual and predicted values compare.

Appendix V consists of tables of all the total and partial correlation coefficients calculated in the course of the investigation.

I—INTRODUCTION

The ultimate and crucial test of any scientific hypothesis is its capacity for predicting what consequences will follow from a given series of facts. It is the central problem of the Technological Laboratory to discover such an hypothesis in the form of an equation which will enable the spinning value of a cotton to be predicted from its fibre-properties. In Part I[1] of the present series of papers a list was given of the various factors which might reasonably be thought to have some influence on yarn-strength; in Part II[1] the relationship was discussed between yarn-strength and fibre-strength, though other fibre and yarn properties were inevitably discussed at the same time. The property of clinging-power has been discussed in Part III[2]; but except for this we have not discussed in detail the fibre-properties of a large number of cottons in relation to the strengths of the yarns that have been spun from them. The importance of fibre-length has been discussed in detail by Gurney,[3] whose discussion is, however, entirely theoretical; in all essentials his views are in harmony with those expressed in Part II. Balls,[4] in his most recent work, gives some results from which he draws the conclusion that the importance of fibre-length has in the past been greatly exaggerated, and that long cottons are suitable for fine spinning, and for strong yarns, not because they are long but because they are generally fine, though this association between length and fineness is not inevitable. On the other hand, attempts have sometimes been made to predict the strengths of the yarns that can be spun from a given cotton, by means of the following simple formula,[5] which takes into consideration the property of fibre-length only—

$$S = \frac{K\{1 \pm \cdot 11a \pm \cdot 01b\}}{C}$$

In this formula

S = (unknown) lea strength (lb.);

K = a constant $\begin{cases} 1600 \text{ for carded yarns;} \\ 1750 \text{ for combed yarns;} \end{cases}$

a = difference in staple measured in sixteenths of an inch above or below one inch (use positive or negative sign according as the staple length is greater or less than one inch);

b = difference in yarn counts above or below 28's (use positive or negative sign according as the count is greater or less than 28);

C = counts of yarn of which the strength is sought.

Another formula based on the fibre-length alone can be derived from certain formulæ given by Winterbottom[6] for selecting the length of staple required for a given count; he states that the formulæ are based on "the lengths of staple in most common use, to show what lengths of fibres may be used . . . . for counts ranging from 10's to 120's in mule twist and weft as well as 100's in ring yarn of ordinary quality." The formulæ are

Length of staple in inches

$$\text{for ring twist} = 0{\cdot}35\sqrt[3]{\text{count}}.$$
$$\text{for mule twist} = 0{\cdot}325\sqrt[3]{\text{count}}.$$
$$\text{for mule weft} = 0{\cdot}30\sqrt[3]{\text{count}}.$$

"By use of the foregoing formulæ the suitable length of staple may be ascertained in the absence of better information."

It may be observed that when the staple length is known, these formulæ enable the highest suitable count to be predicted, for they can all be put in the form

$$\text{Count} = K \times (\text{staple length})^3.$$

$$\text{where } K = \begin{cases} 23 \text{ for ring twist,} \\ 29 \text{ for mule twist,} \\ 37 \text{ for mule weft} \end{cases}$$

A more complicated formula, taking into account not only the fibre-length but also the fibre-strength, has been used by H. H. Willis,[7] who states "the data on fibre-length and strength, as obtained by laboratory methods, were correlated* with data on yarn strength as obtained by manufacturing tests, and a formula was derived for estimating the breaking strength of 28's yarn. This estimating formula has since been applied to some 43 lots of cotton representing varieties grown in North Carolina, South Carolina, and Texas, ranging in staple length from $\frac{13}{16}$ to $1\frac{1}{4}$ inches. Of these 43 lots tested by this method, only 13 showed a variation of more than 6% between the actual and estimated strengths of 28's yarns. The foregoing preliminary data indicate that fibre-length accounts for 61% of the yarn strength and that fibre-strength accounts for 11% of the yarn strength." In the article (abstract) from which this quotation is taken, details are given only for nine lots of North Carolina cottons ranging in staple length from 0·785 to 1·14 in. The differences between the cottons are comparatively small, and although for seven out of the nine cottons the total range in the actual lea strength is less than 7%, yet the estimated lea strength of one of them, Trice (Oxford), is 12·5% too low and that of another, Acala (Oxford), is 7·5% too high, so that the formula is obviously not very satisfactory even when applied within a narrow range of similar cottons. Willis recognises this in commenting—"This method of estimating yarn strength has not yet been fully developed and will no doubt be subject to slight change as more extensive tests are conducted and as various factors influencing yarn strength, as yet undetermined, are measured with some degree of accuracy."

As pointed out in "Technological Reports on Standard Indian Cottons,"[8] however, no complete explanation of spinning value can be given in terms of fibre-length alone, as attempted in the formulæ of Sheldon and Winterbottom; and Willis himself recognises that fibre-length and fibre-strength together are not alone sufficient for the purpose. From values of total correlation between fibre-strength and yarn-strength it would appear that there is but little connection between them. This was pointed out in Part II, wherein it was shown[9] that, for 14 Indian cottons, "the correlation coefficient between the lea count-strength product and the mean fibre-strength is —0·305, and that the correlation coefficient between the count-strength product and the ratio of the fibre-strength to the fibre-weight per inch is only +0·048, "a value which indicates that the count-strength product is not correlated with the ratio of fibre-strength to fibre-weight per inch."

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* The meanings of "correlation" and "correlation coefficient" are discussed on page T12.

Barritt[10] quotes the results of Burd for 10 Sea Island cottons, for which the correlation coefficient between yarn-strength and fibre-strength is —0·41, whereas the correlation coefficient between yarn-strength and the ratio of fibre-strength to fibre-weight per inch is +·031—results similar to those given in Part II. Barritt himself gives the results of tests on 14 samples of Sakel cotton, and found that for them the correlation coefficient between lea count-strength product and the fibre-strength was +0·79, whereas the correlation coefficient between the lea count-strength product and the ratio of fibre-strength to fibre-weight per inch was 0·55. It is noteworthy that the results both of Burd and Barritt relate to very restricted ranges of cottons, and in this respect differ from the results given in Part II for Indian cottons; and the warning there given that the few results must be regarded with caution applies with even greater force when the range of cottons is very restricted.

Tests on a much wider range of 15 samples of cotton have been described by Morton,[11] who states that "in order to simplify the investigation somewhat, an attempt was made to eliminate the effect of hair-length by choosing cottons of nominally the same staple," though actually Morton found that the cottons differed somewhat in fibre-length. "These cottons were spun into a range of different counts and twists, and the results of the strength tests on the yarn were examined in relation to certain of the measurable characters of the raw material, viz. fibre-weight, fibre-length, and fibre-strength." The following are among the results which Morton obtained; in considering these results it should be remembered that for such a small number of samples none of the correlation coefficients referred to can be regarded as statistically significant if it is less than 0·59.

For 24's spun with twist factor 4·0—

Correlation coefficient between lea breaking-length and fibre-strength, —0·61.

Correlation coefficient between lea breaking-length and ratio of fibre-strength to fibre-weight per inch, 0·18.

These results resemble those given in Part II, the correlation of yarn-strength with fibre-strength being fairly large and negative, and that with the intrinsic strength being small and positive.

Correlation between lea breaking-length and mean fibre-length, 0·39.

Correlation coefficient between lea breaking-length and fibre-weight per inch, —0·70.

(In this case the correlation coefficient is much higher for fibre-weight per inch than for fibre-length, but it must be remembered that the range of fibre-lengths was deliberately restricted.)

From some other values given by Morton it is interesting to note that the values of the correlation coefficients are different for different counts, even when all the counts are spun with the same twist-factor, 4·0, thus—

Correlation coefficient between lea breaking-length and fibre-weight per inch, for 24's —0·70; for 40's —0·79.

Correlation coefficient between single thread breaking-length and fibre-weight per inch, for 24's, —0·71; for 40's, —0·80.

According to O. Johannsen,[12] "erroneous results may be obtained in judging the spinning value of a cotton on staple length and strength alone. In an example, an 18's single yarn was spun from a variety P which gave a better staple diagram and a stronger staple than a second variety A spun into a similar 18's yarn. The yarn spun from P possessed higher breaking strength and extensibility than the yarn from A, but when twisted into a 15-fold yarn (5/3) gave a lower breaking strength test than a corresponding 15-fold yarn spun from A. Assuming that the strength of a fibre-structure depends upon the friction between individual fibres and on the specific strength of the material, and that the frictional strength is the more effective the greater the surface of friction, the density of the hairs in the two twist yarns was examined. The twist of P variety cotton was found to have a lower number of hairs per cross-section than the twist of A variety, and it is concluded that the decrease of friction surface on account of the stronger and coarser hair is the cause of the surprising inferiority of the P variety. The deduction is drawn that it is safe to assume that a higher individual hair strength will give a better yarn only when comparing hairs of equal fineness."

Reference has already been made to recent work of Balls,[13] who concludes that "once the fundamental difficulty of instability in singles has been overcome, the relation between cotton and yarn becomes quite reasonable and not very intricate. Fineness by weight acts twice over, as does also slipperiness, while the strength of the cellulose wall itself is the chief remaining factor; the one character of cotton which we have been able in the past to measure easily, namely, length, is definitely less important than any of these three." And in summing up the results of the fibre and spinning tests on 13 American cottons, he claims that "so far as the strength of yarn is concerned, that explanation (of it in terms of fibre-properties) now seems to be complete." But while he maintains that the properties of any other type of yarn could have been predicted, he does not as a result of his investigations actually put forward any prediction-formula.

An investigation on quite different lines has been published by Bühler,[14] who aims not only at assigning the intrinsic spinning value, but also the monetary market value. His system, however, is an empirical one which is based on an arbitrary though comprehensive allocation of points for the various qualities of the cotton, as follows—

	Symbol	Points for Weighting	
1—For Staple and Regularity—			
Mean Staple	A	5	12
Maximum Staple	B	4	
Difference (Maximum—Mean)	C	3	
2—For Cleanliness—			
Maturity			
(*a*) Mature Fibres %	E	2	12
(*b*) Unripe Fibres	F	2	
(*c*) Dead Fibres	G	2	
Content of Foreign Matter			
(*a*) Total	J	3	
(*b*) Seed content	K	3	
3—For Strength—			
Broken and Damaged Fibres %	H	1	6
Breaking Strength	D	5	
			30
4—For Colour	Co	3	3

Bühler shows the application of his system to a series of 11 cottons ranging from Uppers to Oomras. The values of each of the 10 properties (A to K) are given for each cotton, and all the cottons are then ranked for each property. Each value of rank (1 to 11) is then weighted according to the system of points given above, and the average weighted rank (D_g) of each cotton determined for all the properties together apart from colour.

The reciprocal of this average rank $\left(\frac{1}{D_g}\right)$ for any cotton gives a coefficient to apply to U_s, "the basic cost-price for middle quality," to determine the value of that cotton apart from colour; a correction is then applied for colour, a scale of coefficients $\left(\frac{1}{Co}\right)$ being drawn up based on the colours of the American standards (ignoring all the other constituents of grade); these coefficients range from 1 for Middling Fair to 1/7 (0·143) for Low Middling, but are modified somewhat for the degree, if any, to which the cotton is tinged. The formula for the spinning market value (M_w) thus becomes—

$$M_w = U_s + U_s\left[\frac{1}{D_g} + \left(\frac{1}{D_g}\cdot\frac{1}{Co}\right)\right]$$

Finally, allowance is made for the fact that short fibres (taken as those less than 10 mm.) are lost in processing, so that if K_f is the percentage of short fibres, the actual market value for spinning purposes (SP) is given by

$$SP = M_w - (M_w \cdot K_f)$$

Clearly, Bühler's method suffers from some several limitations. Firstly, it may be noted that the agreement between the calculated and observed prices for the 11 cottons discussed by him can hardly be regarded as satisfactory. Secondly, the method is not applicable to an individual cotton, as a whole series must be available in order that the ranking method may be applied; in this respect, as Bühler indicates, the method resembles the trade method, and the difficulty might be overcome by adopting a series of standards of each season's crop by which to rank any other sample. Thirdly, it is not clear how the basic value U_s is fixed: for the cotton whose actual market value for spinning purposes is represented by U_s we must have—

$$D_g = \left(\frac{1}{Co} + 1\right)\left(\frac{1}{K_f} - 1\right)$$

And as the values of K_f for the 11 cottons described range from 0·03 to 0·09, the values of $\left(\frac{1}{K} - 1\right)$ range from 32 to 10; and as $\left(\frac{1}{Co} + 1\right)$ cannot be less than 1, D_g cannot apparently be less than 10—a value higher than the highest value obtained (8·7) for any of the 11 cottons; and moreover this does not seem to agree with his explanation that for the cotton forming the basis of comparison, "all the coefficients were assumed to be unity." Fourthly, the allocation of the points for the different cotton properties is arbitrary. It is, of course, the chief object of the correlation method of the present paper to determine the relative importance of the properties measured. As Bühler recognises, "The value-figures for the individual groups must in particular be the subject of further investigation and more extensive treatment."

Finally, Foster and Gregory[15] have suggested a quite different method of attacking the problem of predicting spinning value. As the strength of an *element* of yarn depends upon its weight and twist, from a knowledge of this relation and also of the variation in the weights of the elements along a yarn, it should be possible to predict the strengths of weak places and their distribution, and hence the strength of any length of the yarn. Their method is therefore directed towards finding how the variation in weight (i.e. the irregularity) depends upon the properties of the cotton, and how the strength of the yarn varies with the weight and twist at the place of break. This method, though *prima facie* it appears to be less direct, may ultimately prove more successful in solving the difficulties presented by anomalous results of the correlation method (see page T25), in fulfilment of their claim that although "this method appears to be even more empirical than the correlation method, . . . actually it promises to yield far more fundamental knowledge of the spinning processes and so lead to a spinning equation which will be more thoroughly understood." No results of an investigation by this method have been published.

We see from the foregoing review that no very comprehensive investigation has so far been published dealing with the relation of a number of fibre-properties to spinning value; and we now pass on to describe the work carried out at the Technological Laboratory. As pointed out in a previous paper,[16] "Our ideal would be the formulation of an equation, so that by inserting therein the appropriate ascertained values for the various properties, we should at once be able to determine, by solving the equation, the counts for which the cotton would be suitable under the standardised conditions. Thus if we represent the length of staple by x, the ribbon-width by y, the area of cross-section by z, and so on, we should have the general equation for the evaluation of C, the finest count for which the cotton is suitable—

$$C = F\ (x, y, z, \ldots\ldots)$$

Unfortunately, little or nothing is known about this function."

In the present investigation, owing to the complexity of the problem, we have been compelled as a beginning to assume the simplest possible form of the function on the right-hand side of the equation x, i.e. that the function is of a linear type, or that the highest standard warp counts $=$ ($a \times$ fibre-length) $+$ ($b \times$ fibre-weight per inch) $+ \ldots$ where $a, b, \ldots\ldots$ are constants. As will be seen later, this assumption of linearity is certainly not really justifiable, but by deriving an approximate formula of prediction we may use it on the material in hand, and afterwards proceed to examine the causes of the departures of the predicted from the actual values, as there is no doubt that the subsequent examination of the anomalies should throw considerable light on the factors concerned in spinning value.

II—CRITERIA FOR JUDGING SPINNING VALUE

The questions arise—What criterion should be used to judge the spinning value of a cotton ? What method of testing should be used for the yarns ? As indicated above (p. T2), the Sheldon formula—and apparently Willis's also —is based on the lea strength of 28's yarn; but leaving aside for the moment the fact that the lea test is sometimes condemned as being an unsatisfactory measure for grading cottons, there is the difficulty that many cottons could not be spun commercially into 28's counts. Moreover, it is certainly doubtful whether this method would distinguish between two cottons at the other end of the spinning-value scale, i.e. if a cotton A is slightly better in lea strength at 28's counts than another cotton B, it is by no means certain that cotton A would also be better than cotton B in say 120's counts. Some support is given to this view by Morton's correlation coefficients between fibre-weight and single-thread and lea strengths, these being higher for the

40's yarns than for the 24's, so that as the fibre-weights are of course the same for both counts there may be some differential effect between the cottons in proceeding from the 24's to the 40's counts. It is concluded, therefore, that the index of yarn quality, lea strength at 28's counts, is only applicable to a very narrow range of cottons.

It is emphasised by Balls[17] that the determination of yarn-strength, for any one length of test-specimen only, is unsatisfactory as a measure of cotton quality, and may indeed be misleading because different comparative results might be obtained merely by altering the length of the test-specimen; this is a consequence of differences between the yarns in their strength-irregularity. An example of such an effect has been given by one of the present authors,[18] in which an apparently anomalous result in some tests of tearing strength was traced to a difference in irregularity of the yarns; the yarns were of the same count and twist, and had the same strength when tested on 18-in. lengths, but different strengths when tested on 3-in. lengths*. Although Balls's[17] "general conclusion is that the lea test is a rational one," he does not accept it as the sole criterion of yarn quality because it is made on a fixed length; and yarns should apparently be tested at many different lengths before a conclusion is drawn as to the spinning quality of the cotton. This of course is a very laborious proceeding, and must be regarded as impracticable under present conditions. Actually, at the Technological Laboratory, it has always been the practice to test the standard cottons on two different lengths of specimen, viz. on 12-in. lengths in single thread tests, and on 120-yard lengths in lea tests, though these two tests are not of course strictly comparable.

In view of these difficulties in connection with the relation of yarn strength to spinning-value, and the consequent difficulties that arise in the attempt to correlate the spinning-value with the fibre-properties, the criterion of spinning-value used in the present paper is the "highest standard warp count," an account of which is given in the next paragraph.

Highest Standard Warp Counts

The highest standard warp count, which has always been used at the Technological Laboratory as a convenient single index of spinning-value, has been described in earlier publications,[20] and is, briefly, the finest count of warp yarn that can be spun economically with a standard medium twist and with only a few breakages in spinning, and have a certain standard strength; the strength referred to is the lea strength, for which the following standard scale was adopted for the different counts.

Count	Lea Strength	Count-Strength Product
Up to 14	90	1260
16	81	1296
18	73	1314
20	67	1340
22	82	1362
24	58	1394
26	54	1404
28	51	1428
30	48	1440
32	46	1472
34	44	1496
36	42	1512
38	40	1520
40	39	1560

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* The theory of the effect of specimen length on the result of a strength test has been very fully worked out by Peirce[19] in terms of the irregularity of strength.

The application of this table is based on the fact that it requires a *higher* count-strength product as the counts become finer, whereas any particular cotton, if spun into various counts, all having the same twist-factor, will give a *lower* count-strength product as the counts become finer. It follows, therefore, that if we spin a particular cotton into too low a count, its count-strength product will be above that required by the table for that count; and as we spin the cotton into finer and finer counts there comes a time when the yarn of a particular count has a count-strength product just equal to that required by the table for that count—and it is this particular count which is designated "the highest standard warp count." In practice a cotton is spun only into two or three counts, chosen usually so that at least one is below and one above the highest standard warp count; by bracketing the highest standard warp count in this way it is a simple matter to estimate its actual value with a considerable degree of accuracy. In assigning the highest standard warp count to a cotton, it was originally intended to take into account not only the lea strength but also the single thread strength and the number of yarn breakages in spinning. But in point of fact it has been only on comparatively rare occasions that the lea test and the single thread test have given substantially different indications of the highest standard warp counts. and in most cases it has then appeared preferable to give greater weight to the lea-test result, both because it is the standard of reference in the industry and because it is much less subject to sampling errors, even when 1200 tests of single-thread strength are made for each cotton. Furthermore, experience has shown that, owing to the comparatively small scale of working, it is unwise to attach too much importance to any but fairly large figures for yarn breakages, and when the figures are large the strengths of the yarns probably give equally good indications of bad spinning quality in the count in question.

III—TESTS AT THE TECHNOLOCIGAL LABORATORY

The tests on which the present analysis is based have been made on the standard Indian cottons, of which a full account is given in "Technological Reports on Standard Indian Cottons, 1930."[21]

Sampling—The Technological Laboratory receives each season 24 lb. of each standard cotton for fibre and spinning tests. Of this, only a very small quantity can be submitted to the fibre tests, and special precautions are therefore taken to make the "sampling for fibre tests" as representative as possible. Small masses of the cotton are selected at random from various parts of the 24 lb. bulk, until a sample weighing about ½ lb. is obtained. This is thoroughly mixed by hand, and is then divided and re-divided until eight practically equal portions are obtained, from each of which a number of tufts (5 or 6) are taken to form the sample to be tested. A number of workers are engaged in the fibre-testing, and each of them does his own sampling from the ½-lb. sample; and as each test is made by at least two workers the degree of agreement between their results affords a general check both upon the accuracy of their sampling and of their testing. As this method deliberately includes the personal equations of different workers it has the consequence of increasing the standard error of any one mean value, but makes more reliable the comparison of different means, obtained in some cases by different workers; moreover, if the individual means obtained by two workers differ by more than 5% in the case of fibre-length or 10% in the case of fibre-weight, repeat tests are made by two other workers before the general mean is taken for the particular fibre-property. Similar repeat tests are carried out in the case of other properties when the two workers obtain appreciably different mean values. Details of the fibre and spinning tests are given in the two following sections.

Details of the Fibre Tests

Fibre-length—The mean fibre-length is determined by means of two different instruments, viz. (1) the Balls sorter and (2) the Baer sorter. Four determinations are made with the Balls sorter, and eight with the Baer sorter; the value taken for the mean fibre-length of each sample in the present paper is the average of the mean values obtained by the two methods.

Fibre-weight per inch—The mean fibre-weight per inch is determined by weighing, on a quartz-fibre torsion micro-balance, groups of 1 cm. lengths cut from the middle portions of straightened bunches of fibres. The number of fibres in a group for weighing depends on the coarseness of the cotton, ranging from 150 for very coarse cottons to 500 for the finest cottons; in all, some 4000 fibres of each sample are weighed. The value of the fibre-weight is corrected for the effect of humidity, and is shown as the mean fibre-weight per inch as at 70% relative humidity.

Fibre-strength—The mean fibre-strength is determined by two methods, viz. (1) the Balls Magazine Hair Tester and (2) the O'Neill Tester, as modified by Mann and Peirce[22]; 300 fibres are tested individually by each method—150 by each of two workers; the value taken for the mean fibre-strength of each sample in the present paper is the average of the mean values obtained by the two methods, corrected to 70% relative humidity.

Fibre-rigidity—The fibre-rigidity at 70% relative humidity is determined from measurements of the time of torsional vibration of a small cylindrical aluminium rod suspended at its mid point by the cotton fibre under test. The value of the fibre-rigidity is calculated from the following formula—

$$R = \frac{8\pi^3 K l}{t^2}$$

> where R is the fibre-rigidity in dyne-cm^2; K is the moment of inertia of the aluminium rod; l the length of the fibre; and t the period of torsional vibration.

The fibre-rigidity is determined for 150 individual fibres maintained strictly at 70% relative humidity, the fibres being the same as already used in the determination of ribbon-width and convolutions (see below).

Ribbon-width—The ribbon-width is determined by measurements under the microscope taken at 10 different points along the length of the fibre, each of these points being situated mid-way between a pair of successive convolutions; 150 fibres are measured in this way.

Convolutions—The number of convolutions is determined under the microscope at the same time that the ribbon-width is measured, using the same fibres; a convolution is regarded as due to the twisting of the fibre on its longitudinal axis through an angle of 180 degrees.

Clinging-power—The clinging-power is determined[23] by measurement of the force required to pull a group of 10 fibres through a pair of pads covered with parallel fibres of the same cotton, the pads being pressed together under a standard pressure; 25 groups of fibres are tested in this way.

Details of the Spinning Tests

As a general rule the spinning tests have been made on two 10-lb. samples of each cotton, each being spun into three types of yarn differing in counts or twist-factor; on each type of yarn there have been made 50 tests for lea strength and counts, and 200 tests for single-thread strength, extension, and counts, besides 100 tests for twist. Thus the assignment of each value of highest standard warp counts has been based on the results of 300 lea tests and 1,200 single-thread tests. These tests have been carried out on standard machines under standard conditions.

Extent of Data Obtained for Indian Cottons at the Technological Laboratory

The present paper gives the results of an analysis of the test-values obtained for no less than 95 samples that have formed the subject of "Technological Reports on Standard Indian Cottons."[20] These standard cottons, numbering 21, have for the most part been subjected to spinning tests since 1924; it was only in 1926, however, that a fairly complete system of fibre-testing was developed by which all the standard cottons have been tested for length, weight per inch, strength, width, convolutions, and rigidity. But samples for which these properties were determined in seasons previous to 1925-26 have also been included. As mentioned in Part III,[23] the clinging-power has also been determined for 45 samples, of which 38 were included among the 95 samples of Series I. One great objection that can be made to earlier discussions of the correlation between spinning-value and fibre-properties is that they refer to so few samples; the 95 samples is a much larger number than any previously discussed. Moreover, these 95 samples have been very extensively tested for far more properties than any set of cottons for which results have been published hitherto. The following are the approximate total numbers of tests done on each series of samples—

SERIES I

FIBRE TESTS

Property	No. of Tests
Fibre-length ...	380 Balls Sorter
	760 Baer Sorter
Fibre-weight ...	1,600 Weighings
Fibre-strength ...	60,000
Ribbon-width ...	14,250
Convolutions ...	14,250
Fibre-rigidity ...	14,250

YARN TESTS

Property	No. of Tests
Lea Strength	28,500
Lea Counts	28,500
Single-thread	
Strength	111,600
Extension	111,600
Counts	5,550
Turns per inch	57,000

SERIES II

FIBRE TESTS

Property	No. of Tests
Fibre-length ...	180 Balls Sorter
	360 Baer Sorter
Fibre-weight ...	700 Weighings
Fibre-strength ...	30,000
Ribbon-width ...	6,750
Convolutions ...	6,750
Fibre-rigidity ...	6,700
Clinging-power ...	1,125

YARN TESTS

Property	No. of Tests
Lea Strength	13,500
Lea Counts	13,500
Single -thread	
Strength	54,000
Extension	54,200
Counts	2,700
Turns per inch	27,000

The mean-values of the several fibre-properties and the spinning-values are given in Appendix III, Table I for Series I samples, and Table II for Series II samples.

After the testing of the 1927-28 cottons the correlation coefficients were worked out for the 51 samples available; in the following season another 22 sets of results became available, and the correlation coefficients were calculated for the 73 samples; similarly, the results became available for the

95 samples in 1929-30, for which the present analysis has been worked out. Since this was started, the results have become available for the two following seasons, and the correlation coefficients have again been worked out for each successive addition of samples. The simple method used for including the results of successive seasons, which aims at keeping the necessary arithmetic to a minimum, is described in Appendix II.

IV—ANALYSIS OF THE DATA: USE AND LIMITATIONS OF THE METHOD OF CORRELATION TO OBTAIN A PREDICTION-FORMULA

The method by which we have obtained our approximate formula for the prediction of spinning-value is known as the method of correlation. The routine application of this method is described in Appendix I. Here we confine ourselves to an explanation of the method, before proceeding to the discussion of the results to which it leads us. By saying that there is correlation between two or more quantities or qualities we merely mean that there is some connection between them; we define the *extent* of the connection by means of the correlation coefficient. For example, the production of a particular count of yarn is connected with the speed of the front roller of the spinning machine; true, it depends upon other things as well, but if we made an investigation of the productions of a large number of mills for this particular count we should in general find that the production was highest when the front roller speed was highest. We should hardly expect a direct proportionality between these two quantities because some mills might be using rollers of slightly different diameters, and certainly the mixings used by different mills would differ; moreover, the spinning machines would not all be of the same age or condition; for these reasons, even if the front roller speeds were the same for two mills for a particular count, it is unlikely that their productions would be exactly the same. But there would be the general connection between the front roller speed and the production, and this connection is indicated by saying that the production is correlated with the front roller speed. If we found that the average production of different mills was exactly proportional to the front roller speed, the correlation would be perfect; but in any actual case we should fall short of this perfect correlation. We therefore need some mathematical index to indicate the degree of correlation; this index is the correlation coefficient, usually represented by the letter r; r has the value 1 for perfect correlation, and some fraction of 1 for any correlation which is not perfect; further, if there is no connection at all between these two quantities or qualities, then these are said to be uncorrelated, and the correlation coefficient between them, as estimated from a large sample, would be practically 0. Obviously all degrees of correlation must be represented between 0 and 1. It may also happen, however, that an increasing value of one quantity may be associated with a generally decreasing value of the second quantity; in such cases the two quantities are said to be negatively correlated, and just as all positive correlation coefficients lie between 0 and 1 so all negative correlation coefficients must lie between 0 and −1.

It has already been stated that the production of a particular count of yarn is highly correlated with the front roller speed. But if we consider the production not of a single count of yarn but of many different counts, the situation becomes more complicated. If we were to spin counts of yarn, twice as fine, keeping the front roller speed and all other factors the same, the production would be only half as great, i.e. as the count number increases so the production decreases, and production and counts are therefore negatively correlated. If we consider both counts and front roller speed together, we clearly have the dependent variable (the production) depending on the two independent variables, the front roller speed and the counts. Obviously, if we were to take into consideration still more factors, our dependent variable, the production, would depend on so many more independent variables. We will now proceed to consider how such relations are expressed in a simple mathematical form, returning for this purpose to our problem of the prediction of spinning value from fibre-properties.

Table I, Appendix I (page T28), shows that if no regard were paid to the fibre-length, a sample of cotton might fall anywhere in the table and so spin anything from 5's to 44's; yet if we impose the restriction that the sample of cotton has a definite fibre-length, it can only fall in one of the various columns of the table, and for any one column the range of counts is decidely less than for the whole table. Moreover, this table reveals what is familiar to every cotton broker or spinner, viz. that, *on the average*, the shortest cottons are only suitable for coarse counts, whereas the longest cottons are suitable for fine counts; this fact is summarised by saying that the count spinnable is correlated with length of staple.

This average relationship can be represented fairly well by a straight line, known as a *regression line*, representing that—

Highest standard warp count = {a constant (b) × length} + {another constant (C)} ....(1)

The constant b in this equation is called a *regression coefficient*, and here means that for every change of length of one unit (say $\frac{1}{16}$ in.), the count changes, *on the average*, by b units in the same direction if b is positive (as it is for changes in fibre-length), and in the opposite direction if b is negative (as it is for changes in fibre-weight per inch). This, then, is a prediction-formula by which we could calculate the counts to be expected on the average from a sample having a certain fibre-length.

It should be noted, however, that whereas in column 3 of the table there are 5 samples with fibre-lengths between 0·66–0·69 in., and all these samples fall in one group spinning from 5's to 8's counts; yet in column 8 there are 19 samples, all having fibre-lengths between 0·86–0·89 in., but not all spinning the same range of counts, for 2 spin from 25's to 28's, 6 spin from 29's to 32's, 9 spin from 33's to 36's, and 2 spin from 37's to 40's. Evidently, then, if a sample has a fibre-length between 0·86–0·89 in., we still cannot say exactly what counts it will spin—the counts might be anything from 25's to 40's; this is because some other properties besides fibre-length affect the counts spinnable. At the same time, this range of counts is much less than the range of 5's to 44's that applies to the whole table. Another question therefore arises, viz. although the average values of count for various fibre-lengths can be represented fairly well by a straight line, how nearly do the *individual* values actually fall on this line ? The answer is that this depends on the *degree* of correlation between the counts and fibre-length; the more nearly the individual values fall on the regression line, the higher is the degree of correlation; if there were no other factors but fibre-length affecting the count, all the individual values would actually fall on the regression line and the correlation would be perfect. The coefficient of correlation r is an index of this degree of correlation; as already indicated, for perfect correlation $r = 1$; thus, in our example of counts and fibre-length, we should say that if $r = 1$

the fibre-length is all important, and for a cotton having any particular mean fibre-length there is a definite highest standard warp count. But if $r = 0$, and there is no correlation between these properties, it would follow that a knowledge of the fibre-length of a sample would tell us nothing about the counts to which it could be spun. Actually, however, for highest standard warp counts and fibre-length, $r = 0{\cdot}87$, which indicates that fibre-length is an important property, but that other properties also have some effect on the highest standard warp count.

It is desirable therefore to extend the regression equation so as to include these other fibre-properties; if we include fibre-weight per inch, ribbon-width, fibre-strength, convolutions, and rigidity, we may write the new regression equation as—

Highest standard warp counts = {a constant (b_2) × length} + {a constant (b_3) × weight per inch} + ... + {a constant (C_1)} ....(2)

It should be observed that the correlation coefficient of 0·87 for highest standard warp counts and fibre-length may be so high, partly because coarseness of fibre (weight per inch) also affects the counts spinnable, and greater length is generally associated with less coarseness of fibre. The latter association affects the value of the regression coefficient b in equation (1); hence if we include weight per inch separately in our extended regression equation, we should use a regression coefficient for fibre-length which is independent of any association of fibre-length with fibre-weight per inch; in other words, in equation (2) the regression coefficient of length does not include any effect due to any other of the fibre-properties included in the extended regression equation; though it does, of course, still include effects due to fibre-properties not included in this regression equation. To distinguish the new regression coefficient of length from that of the other fibre-properties in the extended regression equation, it is written b_2 instead of b, and is termed a *partial regression coefficient*; the original b is a *total* regression coefficient because it includes the total effect of the fibre-length and of the other fibre-properties so far as they affect the regression of fibre-length. Equation (2) is similarly termed a *partial regression equation;* its significance is as follows—if cottons are selected having the same values for all fibre-properties mentioned in equation (2) except length, then for every change of length of one unit, the count changes *on the average,* by b_2 units.

As indicated above, the correlation coefficient of 0·87 between highest standard warp counts and fibre-length may be so high because of correlation between fibre-length and other fibre-properties; thus this coefficient is a *total* correlation coefficient. And just as a partial regression coefficient is used to indicate that the effects of one or more of these other fibre-properties on the regression coefficient for fibre-length have been eliminated, so a *partial correlation coefficient* is similarly used to indicate the degree of correlation between two properties when the effects of one or more other properties have been eliminated. It may be noted that a partial correlation coefficient may be less or greater than the corresponding total correlation between two properties. For example, the total correlation coefficient between highest standard warp counts and fibre-length is 0·87, but when the effect of the correlation with fibre-weight per inch is eliminated, the partial correlation coefficient between highest standard warp counts and fibre-length falls to 0·74; on the other hand, the total correlation coefficient between fibre-convolutions and fibre-rigidity is −0·13, whereas when the effect of the correlation with fibre-weight per inch is eliminated, the partial correlation coefficient rises to 0·45.

Finally, the question may be asked, when a number of fibre-properties are taken into consideration, do the variations in these account for the variation in highest standard warp counts ? Just as the coefficient of correlation *r* indicates the degree of correlation between the highest standard warp counts and a single fibre-property, so a *coefficient of multiple correlation* R is used to indicate the degree of correlation between the highest standard warp counts and all the fibre-properties taken into consideration; at the same time R indicates the degree of correlation between the actual values of the highest standard warp counts and the predicted values obtained from the regression equation for all the fibre-properties taken into consideration.

The relations on which the various calculations depend, and a more detailed explanation of the working, are given in Appendix I, which also contains a brief account of two alternative and somewhat simpler and shorter methods of calculating the partial regression coefficients. As there explained, all three methods lead, as of course they should, to the same regression equations for calculating the average highest standard warp counts from the various fibre-properties. These equations are—

For the Series I cottons—

$$X_1 = 71{\cdot}6\,X_2 - 70{\cdot}8\,X_3 - 20{\cdot}8\,X_4 + 17{\cdot}9\,X_5 + 0{\cdot}037\,X_6 + 4{\cdot}4\,X_7 - 14{\cdot}1$$

For Series II cottons—

$$X_1 = 42{\cdot}7\,X_2 - 66{\cdot}4\,X_3 - 49{\cdot}3\,X_4 - 18{\cdot}7\,X_5 + 0{\cdot}0277\,X_6 + 21{\cdot}8\,X_7 - 26{\cdot}2\,X_8 + 39{\cdot}5.$$

In these equations

X_1 = highest standard warp counts,
X_2 = fibre-length,
X_3 = fibre-weight per inch,
X_4 = ribbon-width,
X_5 = fibre-strength,
X_6 = fibre-convolutions,
X_7 = fibre-rigidity,
X_8 = fibre clinging-power.

In Appendix I are also given the simple regression equations for the average highest standard warp counts in terms of each fibre-property separately, ignoring the effects of the other fibre-properties instead of allowing for them as in the regression equations given above, which take into account all the measured fibre-properties at the same time. Other regression equations are given in the same Appendix I (page T33), which take into account some but not all of the measured fibre-properties, viz. (1) fibre-length and fibre-weight per inch; (2) fibre-length, fibre-weight per inch, and fibre-strength; (3) fibre-length, fibre-weight per inch, and ribbon-width; and (4) fibre-length, fibre-weight per inch, ribbon-width, and clinging power.

These regression equations, then, are the prediction-formulæ that we seek, to enable us to predict the highest standard warp counts from certain measured fibre-properties. But before proceeding further, it is essential to realise that these regression equations suffer from some severe limitations. In the first place, strictly speaking, they merely epitomise the data from which they are derived, and show what is the *average* highest standard warp counts for the given values of the fibre-properties of the samples tested—and even this involves the assumption that there is a true linear relation between the highest standard warp counts and the individual fibre-properties. This assumption is not really legitimate, as is clearly shown by Figs. 1–7, giving the regression curves for the highest standard warp counts and the seven individual fibre-properties, viz. length, weight per inch, ribbon-width, strength, convolutions, rigidity, and clinging power. It may be observed that in the first three cases both curves approximate to straight lines, whereas in the other cases the curves cannot be regarded as linear. In spite of this fact, the regression curves have been assumed to be linear in the present paper. If

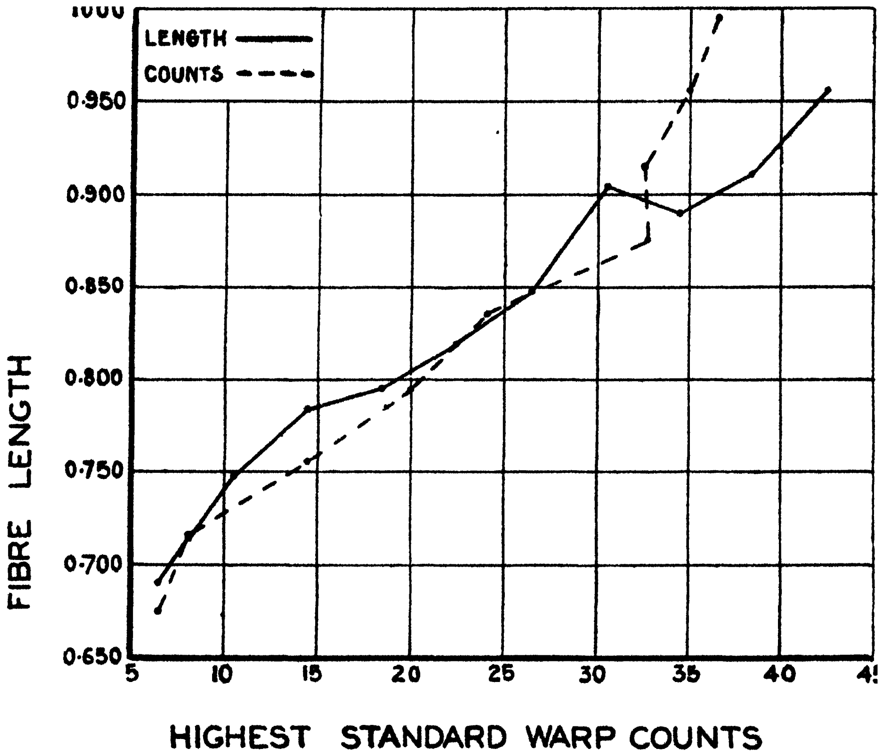

FIG 1— Regression lines for length (on counts) and counts (on length).

then we regard these regression equations as our prediction-formulæ, it is evident that on substituting the appropriate values of the fibre-properties of some particular sample, we assume that this sample belongs to the same universe as those from which our regression equation was derived and even then we shall only obtain the *average* value of the highest standard warp counts for such a set of fibre-properties; and the actual value will differ more or less from this average value; the likely extent of such difference is indicated by the standard error of estimate of the highest standard warp counts, which may be calculated from the data; the actual differences in the present investigation will be discussed in the next section.

Secondly, it is to be observed that even in the tests of Series I the data refer only to 95 samples. Though this is a much larger number than has been the subject of other investigations, and the correlation coefficients do not seem to change much as the number of samples increases with the seasons, it is desirable to emphasise that this number of samples is exceedingly small for the application of the method of multiple correlation when the number of independent variables (the fibre-properties) is comparatively large, and, as Yule[24] observes, "when only a small number of observations are available, it is . . . . little use to deal with a large number of variables." Moreover, as the number of independent variables increases, the arithmetical calculations of partial correlation coefficients, etc. should be carried to a large number of decimal places in order to obtain a final accurate result for the constants of the regression equation—"probably something like one additional decimal place for each variable involved."[25] Such a procedure adds enormously to the great labour involved in the calculations, and in view of the facts already mentioned, has not been followed in the present investigation.

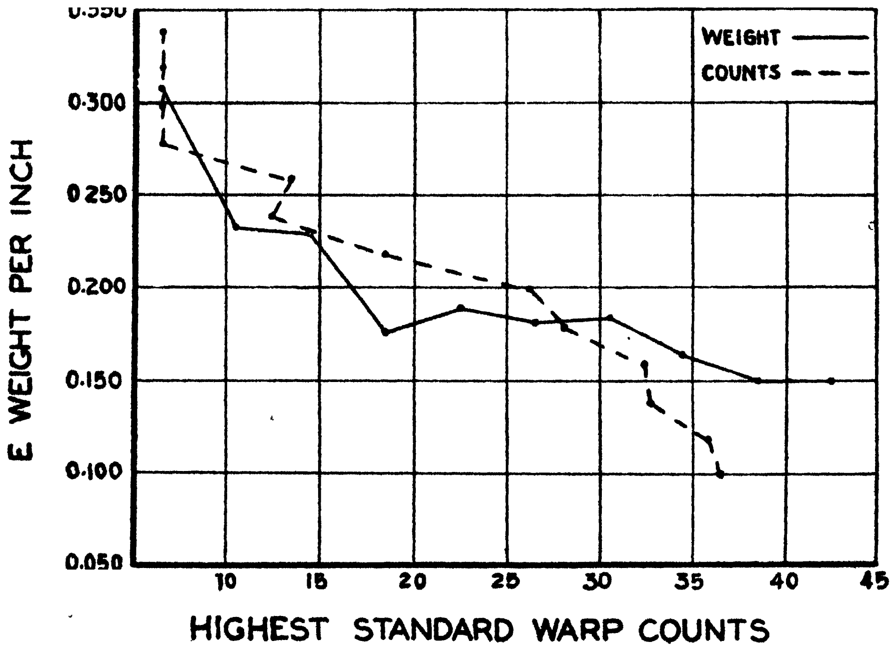

FIG. 2—Regression lines for weight per inch (on counts) and counts (on weight per inch).

Thirdly, although the number of samples of Series I was 95, the number of different varieties of cotton was only about 20, these forming the subject of tests in successive seasons. And while the seasonal repetition of the tests is desirable in order that the general prediction-formula may include any seasonal effects, the number of types of cotton to represent the universe of types, to which the theory of correlation relates, is of course restricted. At the same time, it may be noted that the standard Indian cottons do include all the types commonly grown in India, and represent a wide diversity of type and also of district and conditions of growth.

V—VALUES OBTAINED FROM THE DATA FOR CERTAIN COEFFICIENTS OF CORRELATION AND REGRESSION

As will be seen from the following table, the total correlations between the highest standard warp counts and the various fibre-properties have not changed much as more values have become available in the successive seasons—

Correlation Coefficients between Spinning-Value and Fibre-Properties as the number of Samples increases in Successive Seasons

Seasons up to and including ...	1927–28	1928–29	1929–30	1930–31	1931–32
Number of Cotton Samples ...	51	73	95	110	134
Total Correlation between Highest Standard Warp Counts and—					
Fibre-length	+0·83	+0·85	+0·87	+0·87	+0·87
Fibre-weight per inch	−0·80	−0·81	−0·80	−0·79	−0·79
Ribbon-width	−0·75	−0·73	−0·69	−0·71	−0·71
Fibre-strength	−0·38	−0·39	−0·33	−0·34	−0·35
Convolutions	+0·49	+0·47	+0·46	+0·46	+0·45
Fibre-rigidity	−0·71	−0·69	−0·67	−0·69	−0·70

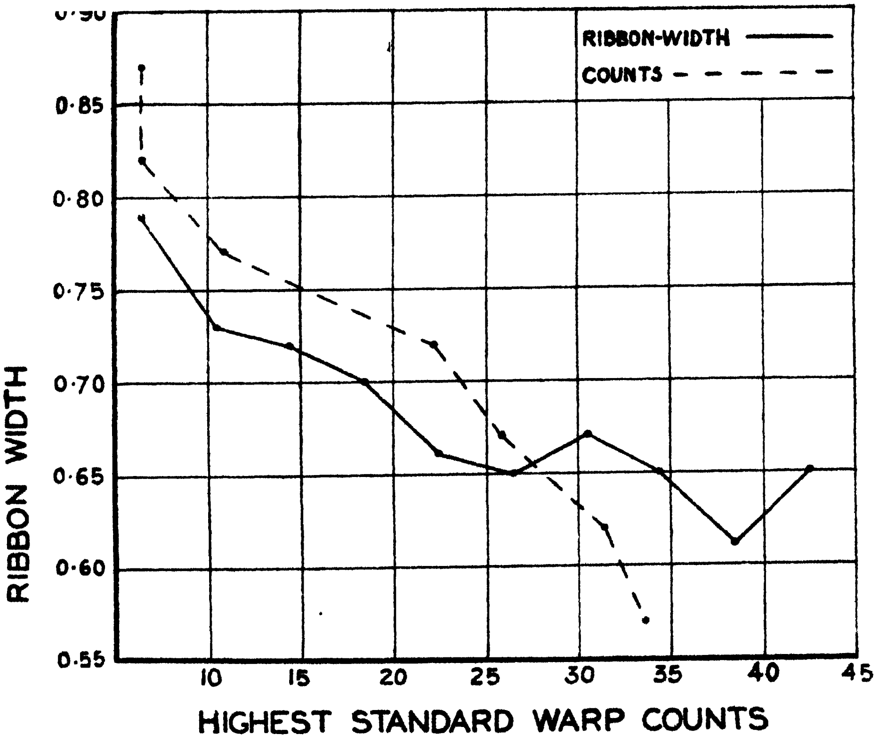

FIG. 3—Regression lines for ribbon-width (on counts) and counts (on ribbon-width).

In connection with these results it may be noted that the fibre-weights have been determined by a different method in 1930–31 and 1931–32, and although a correction has been applied to them with a view to making them comparable with those of previous seasons, it has been considered undesirable to use them for the complete analysis given in this paper; even if the additional data had been used they would have caused only very small changes in the correlation coefficients. Further, in view of these changes being so small, it appears that the values now given may be accepted with considerable confidence as applying to the complete range of cottons at present grown in India.

As it is the practice of the Laboratory to determine the fibre-length and fibre-weight of all cottons submitted by the Agricultural Departments of the various Provincial Governments of India, as well as the spinning-values of the cottons, much additional information is available for calculating the correlation coefficients between these particular properties. Some difficulty is encountered in combining the results for these samples with those for the standard Indian cottons, in that the mean values for the standard cottons have in most cases been obtained from twice as many tests as those for the Agricultural Department samples. In the following table we accordingly give the correlation coefficients for these non-standard cottons, both separately

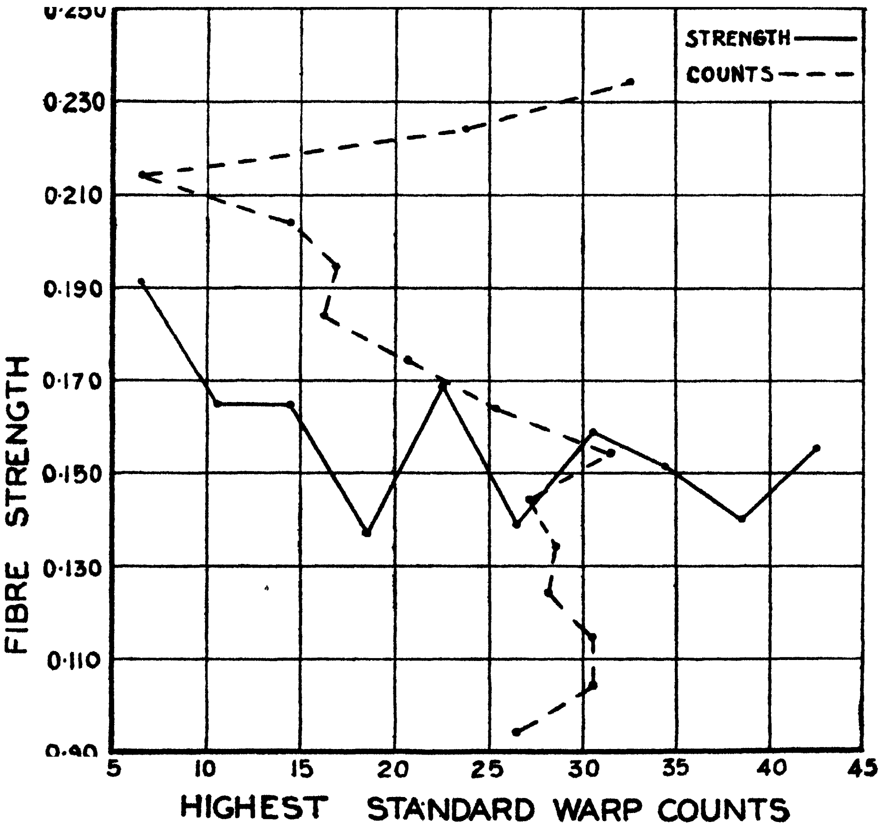

Fig. 4—Regression lines for strength (on counts) and counts (on strength).

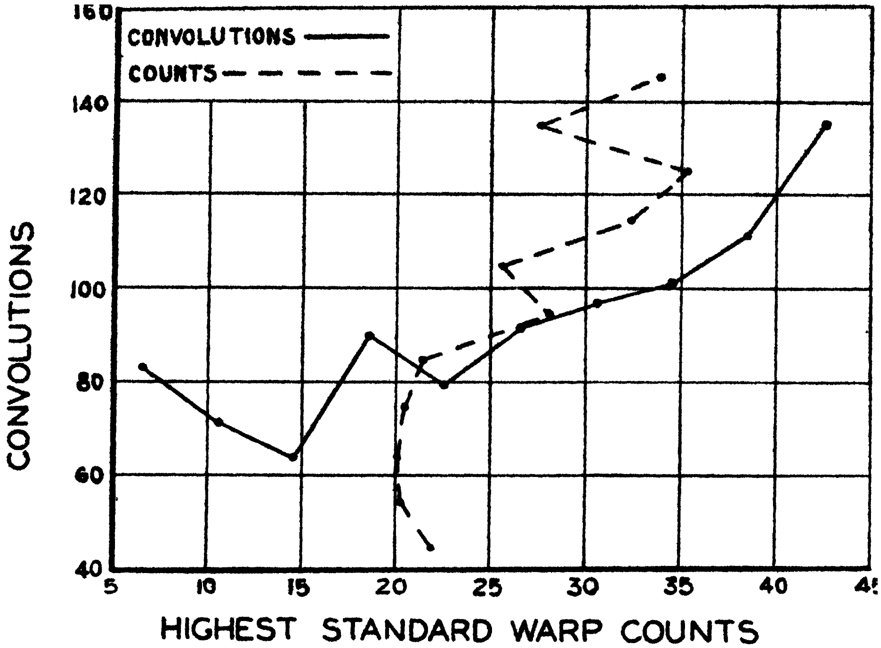

FIG. 5—Regression lines for convolutions (on counts) and counts (on convolutions).

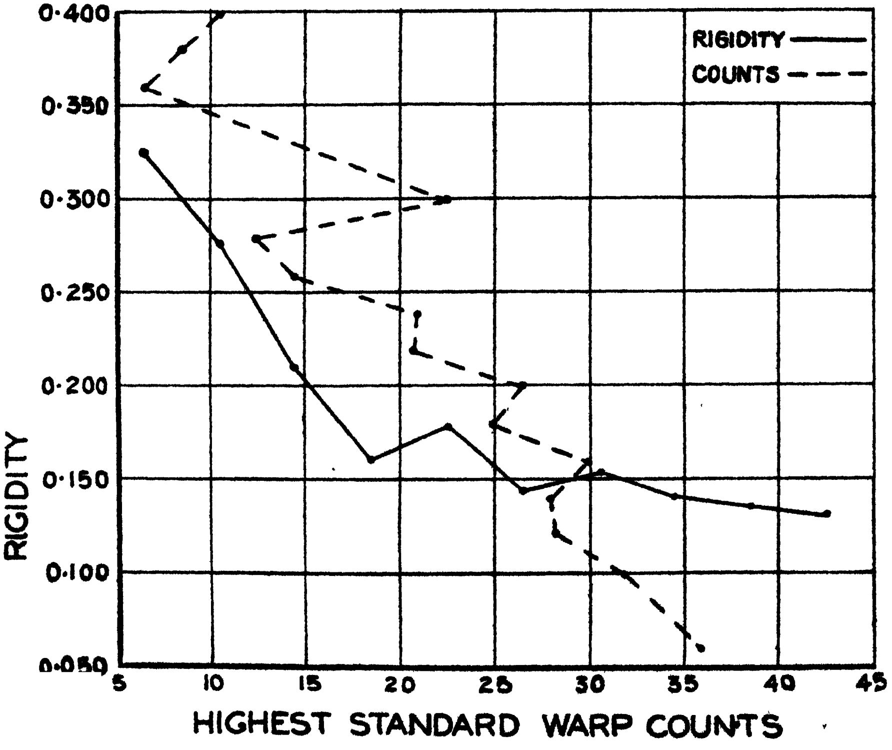

FIG. 6—Regression lines for rigidity (on counts) and counts (on rigidity).

and also combined with those for the standard cottons to which double weight has been assigned where necessary.

Number of Samples Correlation between	95 (Standard Samples)	274 (Non-standard Samples)	460 (Equivalent non-standard Samples)
H.S.W.C. and Fibre-length	0·87	0·86	0·87
H.S.W.C. and Fibre-weight per inch ...	−0·80	−0·71	−0·75
Fibre-length and Fibre-weight per inch	−0·68	−0·58	−0·62

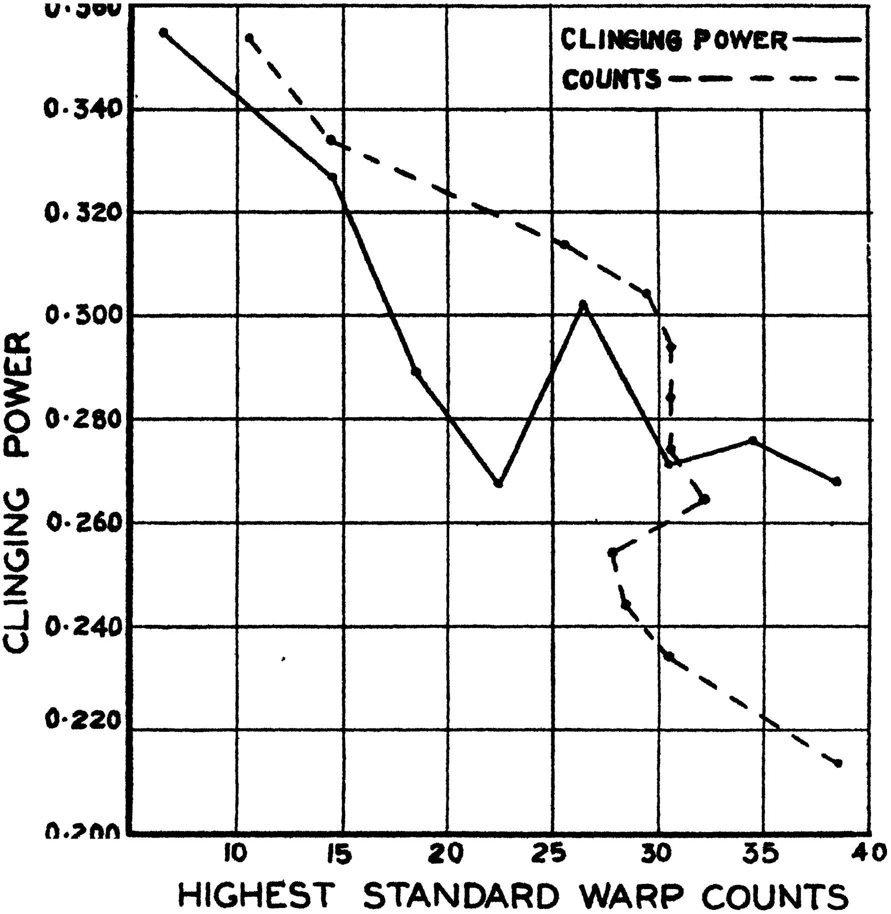

FIG. 7—Regression lines for clinging power (on counts) and counts (on clinging power).

These correlation coefficients are very high and are all statistically significant. Though almost entirely restricted to Indian cottons, they are based on much more extensive data than has been published hitherto; unfortunately, they cannot be compared with the correlation coefficients given by Morton,[10] as he correlated the fibre-properties with yarn strengths and not with the highest standard warp counts.

In the present paper we have also calculated the more interesting partial correlation coefficients, which show the effects to be attributed to the several fibre-properties when unaffected by some or all of the other properties measured. These partial correlation coefficients are given in Tables I and II of Appendix V; those obtained by eliminating the effects of the other five measured fibre-properties of Series I and the six measured fibre-properties of Series II, are as follows—

Partial Correlation Coefficient between Highest Standard Warp Counts and—	Series I (95 Samples) (5th Order)	Series II (45 Samples) (6th Order)
Fibre-length	0·70	0·52
Fibre-weight per inch	−0·36	−0·23
Fibre-width	−0·23	−0·44
Fibre-strength	0·10	−0·07
Fibre-convolutions	0·20	0·16
Fibre-rigidity	0·06	0·16
Fibre clinging-power...	—	−0·19

In each case the partial correlation coefficient is much less than the corresponding total correlation coefficient. Indeed, tests of statistical significance[26] show that, with 95 samples from a population in which there is actually no correlation between properties, the chance is 1 in 100 that the fifth order partial correlation coefficient will be as high as 0·27 by random sampling alone, and 1 in 20 that it will be as high as 0·21; with 45 samples from such a population, the chance is 1 in 100 that the sixth order partial correlation coefficient will be as high as 0·41 by random sampling alone, and 1 in 20 that it will be as high as 0·32. These statistical tests show that, for the 95 samples of Series I, only the partial correlations of fibre-length and fibre-weight per inch can be regarded as significant if the more stringent test be applied, though with the less stringent test the partial correlations of fibre-width and fibre-convolutions must also be regarded as just significant.

The same conclusion* is arrived at from a consideration of the partial regression coefficients of the regression formulæ that take into account all the fibre-properties measured, viz. the equations already given on page T15. We will confine our attention to the equation for the Series I samples, as the constants of this equation have been determined from the larger number of samples. The standard errors of the partial regression coefficients of this equation have been calculated, because the ratio of a coefficient to its standard error furnishes a measure of the statistical significance of the coefficient in question. The results are as follows—

Regression between Highest Standard Warp Counts and	Partial Regression Coefficient (5th Order)	Standard Error of Partial Regression Coefficient	Statistical Significance of Partial Regression Coefficient
Fibre-length	71·6	10·9	Significant
Fibre-weight per inch ...	−70·8	21·1	Significant
Fibre-width	−20·8	9·6	Doubtful
Fibre-strength	17·9	18·5	Not Significant
Fibre-convolutions	0·037	0·019	Doubtful
Fibre-rigidity	4·41	8·2	Not Significant

In this table the fifth order partial regression coefficients of fibre-length and fibre-weight per inch are alone classed as significant; these regressions are significant even with the more stringent test of significance that such a result would not be obtained more than 1 in 100 times as a consequence of random sampling; with the less stringent test of a result being regarded as significant when it would not occur more than 1 in 20 times merely as a consequence of random sampling, the partial regressions of fibre-width and fibre-convolutions are also significant.

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* It is of course inevitable that the same conclusion should be reached seeing that this consideration of the partial regression coefficients is merely an alternative method of dealing with exactly the same data.

It has already been remarked that the fifth order partial correlation coefficients are much smaller than the corresponding total correlation coefficients; the change, however, is much less in the case of the fibre-length than for any other property, and as the total correlation was itself highest for the fibre-length, the fifth order partial correlation is very much higher for fibre-length than for any other property. It follows, therefore, that so far as the partial correlation analysis can be applied to these data, it leads to the conclusion that fibre-length is much the most important property of Indian cottons in determining the degree of fineness to which they can be spun, and that fineness of the fibre itself is usually of importance chiefly because of its common association with length.* Further, these results lead to the very important conclusion that in general it is only worth while determining the values of the properties of fibre-length and fibre-weight per inch. And it will be seen later (page T24), that from these two properties alone it is possible to predict the highest standard warp count almost as accurately as from all the fibre-properties that have been measured in the course of this investigation.

VI—ACCURACY OF THE PREDICTION-FORMULA FOR SPINNING VALUE AND A DISCUSSION OF CERTAIN ANOMALOUS RESULTS

When we have obtained our prediction-formula, the question arises, how trustworthy is the formula ? We can test it in two simple ways as follows—First, we may determine the fibre-properties of a number of other cottons and see how the spinning-values calculated from these fibre-properties compare with those determined by actual spinning; and secondly, we may apply the formula to the results from which the formula has actually been derived, and again see how the calculated spinning-values compare with the actual for the individual samples. The second method is of course a less severe test because in the nature of the case the calculated and actual spinning-values must agree on the whole, and the restriction is obviously imposed that the test-sample does belong to the same universe as the samples from which the formula has been derived; so that all that this method really does is to reveal the cases that diverge widely from the average. Its utility lies in this, however, that it does reveal such anomalous cases, for which a complete theory of spinning-value, in terms of fibre-properties, has to account.

In the present investigation the second method has been applied systematically, and in Appendix IV, Table I for the Series I samples, and Table II for the Series II samples, are given the highest standard warp counts as actually obtained, and as calculated from the various prediction-formulæ derived for Series I and Series II according to the particular fibre-properties taken into consideration.

If we consider first the prediction-formula derived from the fibre-length alone, for which the correlation coefficient is highest, we note that in fact the prediction-formula usually gives quite fair agreement with the experimentally determined highest standard warp counts, to this extent justifying the formulæ of Sheldon, Winterbottom, and Willis; in 51% of the cases the divergence between the actual and predicted highest standard counts does not amount to more than 10% of the actual value; in 69% of the cases the difference does not exceed 20%. But there are a few cases of extreme discrepancy, the most glaring being for Gadag I of 1924-25 compared with 1926-27; the actual values of highest standard warp counts were 20's and 38's in these two seasons, whereas the prediction-formula for fibre-length would ascribe 22's for both seasons. The fibre-weight per inch is less highly correlated with the highest standard warp counts than is the fibre-length; and for the fibre-weight per inch it is only for about 33% of the cases that the divergence between the actual and predicted highest standard warp counts does not amount to more than 10% of the actual value. Nor does the fibre-weight per inch enable us to account for the exceptional case of Gadag I referred to above, for in this case the prediction-formula ascribes 32's for the actual 20's of 1924-25, and 29's for the actual 38's of 1926-27.

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* It should be observed that this conclusion, that fibre-length is more important than fibre-weight in determining spinning value, may be at least partly due to the impossibility of setting ⅞-in. rollers sufficiently close to permit of the shortest cottons yielding their best results. Hence it would obviously be unwise, on the evidence of the present tests, to extend this conclusion to longer cottons which are suitable for much higher counts than those spun in these tests, and for which the most suitable settings could always be employed.

From Tables I and II of Appendix IV it is found that when both fibre-length and fibre-weight per inch are taken into consideration, the prediction-formula agrees with the actual results within 10% in 44% of the cases, and within 20% in 76% of the cases. No better results are obtained when either fibre-strength or fibre-width is included in addition; even when all six fibre-properties are considered together, the result is not much better than when only fibre-length and fibre-weight per inch are considered—or even fibre-length alone—the prediction-formula in this case agreeing with the actual results to within 10% in 49% of the cases and to within 20% in 80% of the cases. A slightly closer agreement is given by the results for the 45 samples of Series II, when seven fibre-properties are considered, as in this case the prediction-formula agrees with the actual results to within 10% in 53% of the cases, and to within 20% in 96% of the cases.

The results for Series I samples are summarised, with others, in the following table showing the percentages of samples of which the actual highest standard warp counts are within 10% and 20%, respectively, of the values obtained by means of the various prediction-formulæ, derived either for a single fibre-property, or for two or more fibre-properties together; as a basis of comparison, a similar calculation has been made to determine the percentages of samples for which the actual highest standard warp counts do not differ from the grand mean highest standard warp count by more than 10% and 20%, and these percentages are shown in the bottom line of the table as derived from "no formula."

Predicted Values derived from Prediction-Formula for—	Percentage of Samples for which the actual Highest Standard Warp Count does not differ from the Predicted by more than—	
	10%	20%
Length only	51	69
Weight per inch only	33	53
Length and Weight per inch	44	76
Length, Weight per inch, and Strength	44	75
All six fibre-properties	49	80
No Formula	18	29

From this Table it is again clear that the formula for "fibre-length only" is decidedly more accurate than that for "fibre-weight per inch only"; that the formula for length and weight per inch together is rather better than that for length alone (but only for the 20% level); and that the formula for all six fibre-properties is only slightly more accurate than that for length and weight per inch together. All the prediction-formulæ give much better results than using "no formula."

The question arises whether the differences in accuracy between the various prediction-formulæ are statistically significant. We can test this by means of the multiple correlation coefficients between highest standard warp counts and the several prediction-formulæ, for, as already pointed out (page T15), the multiple correlation coefficient for any prediction-formula also indicates the degree of correlation between the actual values of the highest standard warp counts and those predicted by the formula. The method of calculation of the multiple correlation coefficients is given in Appendix I (page T36); the total correlations in the case of the single properties of length and weight per inch, and the multiple correlation coefficients in the case of combinations of properties are as follows—

Predicted Values derived from Prediction-Formula for	Correlation Coefficient between Actual and Predicted Values of Highest Standard Warp Counts		Square of Correlation Coefficient in Column 2	
	r	R	r^2	R^2
Length only	0·87	—	·7569	—
Weight per inch only	−0·80	—	·6400	—
Length and Weight per inch (R′)	—	·9153	—	·8377
Length, Weight per inch, and Strength (R″)	—	·9175	—	·8418
All six properties	—	·9285	—	·8622

The squares of the values of the correlation coefficients show that 64% of the variation in spinning-value can be accounted for in terms of the total correlation with weight per inch alone, whereas 76% is accounted for in terms of the total correlation with fibre-length alone; when fibre-length and fibre-weight per inch are taken together, 84% of the variation in spinning-value can be accounted for, and no improvement is obtained by including fibre-strength also; with all six fibre-properties included there is a slight improvement, 86% of the variation in spinning-value being then accounted for, leaving 14% to be accounted for otherwise. Applying the tests of statistical significance to these correlation coefficients, we find all the differences between them are in fact statistically significant except the difference between R′ and R″, which is of course only to be expected from the fact that the inclusion of fibre-strength makes practically no difference to the accuracy of prediction obtained with the two properties of length and weight per inch together. Even the slight improvement obtained with all six fibre-properties compared with length and weight per inch together, is statistically significant, as it would be expected to happen by chance less than 1 in 100 times. But while the determination of four more fibre-properties does thus appear to lead to a real gain in accuracy of prediction of the spinning-value, yet, as previously indicated, the gain is so small that it cannot be considered worth the extra labour that it entails.

Anomalies—The fact that the actual and calculated spinning-values differ by more than 20% in 19 of the 95 cases with six fibre-properties and in 2 of the 45 cases with seven fibre-properties, shows that there remain many anomalies even when so many fibre-properties are taken into consideration. The two anomalous cases with seven fibre-properties are both of Gadag I, viz. 1924-25 and 1926-27 (Table II); the prediction-formula ascribes 28's counts to each cotton, whereas the former was actually found to be suitable for 20's and the latter for 38's. And if the properties of the two samples be compared in detail, it is very difficult to account for the difference in spinning-value; indeed, they have practically the same mean fibre-length, and it is the sample having a much lower hair-weight that has the inferior spinning-value. It is very interesting, however, to note that the cotton grader, when valuing the 1924-25 sample, considered it to be "inferior to 1923-24 sample and not a fair sample of Gadag cotton."

The same cotton presents other anomalies; thus the sample of 1926-27 may also be compared with sample B of 1927-28; the two samples have practically the same mean length, hair-weight, ribbon-width, and convolutions, but sample B has 15% greater fibre-strength, 18% greater fibre-rigidity, and 9% less clinging-power—and yet spins only up to 24's as against the 38's of the 1926-27 sample. Again, the 1928-29 sample closely resembles the 1926-27 sample in all fibre-properties, and yet spins only up to 26's as against 38's.

Even more anomalies are apparent when the six fibre-properties of the 95 samples are considered. Some occur among the low-count cottons, and may be partly attributed to the large effect of a difference of a single unit of counts at such low counts and to the assignment of counts being in integral values only. Gadag I is again responsible for a number of anomalies; another marked anomaly is presented by Punjab-American 285F in seasons 1925-26 and 1929-30. Most of the fibre-properties are almost identical in these two seasons and the prediction-formula assigns the same count to each, viz. 35's, though actually the 1925-26 sample was found suitable for 28's and the 1929-30 sample for 42's. In this case it is just possible that the difference is due to a difference in fibre-strength, as the 1929-30 sample is some 9% stronger—though, as the prediction-formula for six fibre-properties shows, such a difference in the fibre-strength does not in other cases lead to such a difference in the spinning-value.

Many other similar, if less conspicuous, anomalies might be pointed out. The existence of such anomalies demands an explanation. The difficulty, however, lies rather in deciding between a number of possible alternative explanations, to which reference may now be made.

In the first place, in the mathematical treatment it is assumed that the highest standard warp count is related linearly to each of the fibre-properties, and this is certainly not so for the properties of fibre-strength and fibre-rigidity.

Secondly, all the correlation coefficients that have been used in obtaining the multiple regression equation have been calculated from only the average values of the fibre-properties of the various cotton samples; but although the average values of any fibre-property may be the same for two cottons, the variabilities of the properties may be different, and these may contribute to a difference in spinning-value.

Thirdly, if reliance be placed on the regression equation for only the two properties of fibre-length and fibre-weight per inch (page T33), it may happen that two cottons have the same mean fibre-length and the same mean fibre-weight per inch, so that the prediction-formula would ascribe to them the same highest standard warp counts; and yet one may have a large diameter with a thin cell-wall, and the other a small diameter with a thick cell-wall—

differences of a fundamental kind that could hardly leave the spinning value unaffected. It is to distinguish such cases that a test for immaturity is most valuable.

Fourthly, the cotton fibres of the yarn are not exactly those that comprised the raw cotton, as in the various preparatory processes of spinning some lint is removed as waste, having a rather shorter mean length than the raw cotton, and other fibre-properties also are slightly different. Yet the raw cotton must be used in the determination of fibre-properties when these are required for the prediction of spinning-value. However, tests on this point have shown that the differences in fibre-properties between the yarn and the raw cotton are not serious, so that they may be regarded as merged in the errors of experiment and sampling.

Fifthly, although the value for the fibre-strength of any of the samples tested is an average that has been obtained by the testing of 600 fibres individually, it is not the same kind of average as the average values for fibre-length or fibre-weight per inch, for it merely represents the average strength of the weakest points in the 600 fibres; and most parts of any fibre are at least three or four times as strong as its weakest point.[27] But when fibres are twisted together to form yarn, the useful strength of a fibre may be decidedly higher than that of its weakest point; hence, not only the variability of strength from fibre to fibre, but also the degree of regularity of strength along each individual fibre may have considerable effect upon the yarn strength and the spinning-value of the cotton. This affords another reason, beside those given on page T25, for not making further determinations of fibre-strength on individual fibres; at the same time, it provides a reason for making some tests on the strength of twisted bundles of fibres.

It is possible that some of the anomalous results could be explained if data were available about the fibre-strength of twisted bundles and the degree of immaturity of the cottons, and if the degrees of irregularity of fibre-length and fibre-weight per inch were also taken into consideration. In any case it is evident that the investigation of these anomalous cases presents most hope of arriving at a solution of the main problem, so far as this is possible along the lines discussed in the present paper.

APPENDIX I

Note on the Use of the Method of Correlation for Finding a Prediction-Formula in Terms of Fibre-Properties

The general meaning of correlation, and the explanation of the correlation coefficient as a mathematical index of the degree of correlation, have already been given (page T12). The correlation coefficient between two variables X_1 and X_2 is written r_{12}, and its value is given by the formula $r_{12} = \frac{\Sigma x_1 x_2}{N\sigma_1\sigma_2}$, where σ_1 and σ_2 are the standard deviations of X_1 and X_2, N is the number of pairs of observations of X_1 and X_2, and x_1, x_2 are the deviations of the individual observations from their arithmetic means.* Standard deviation, mean, etc., have been defined in a previous Bulletin.[28]

For the purposes of the present paper, the correlation coefficients have been calculated by the direct application of this formula, this being the simplest procedure when the number of observations is comparatively small. These correlation coefficients have been obtained not only between the spinning value and the several fibre-properties but also between the various pairs of fibre-properties, as these are needed in subsequent calculations. For the 95 samples of Series I, with six measured fibre-properties, there are 21 of these correlation coefficients; for the 45 samples of Series II, with seven measured fibre-properties, there are 28 of these correlation coefficients. These correlation coefficients are given in column 1 of the Tables of Appendix V.

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*It may be noted that, throughout, the notation adopted is to use capital letters such as X_1 to indicate observation values, and small italic letters with the same subscripts, such as x_1, to indicate the corresponding deviations of the individual observations from their arithmetic means.

Table I

Fibre-length Class-intervals ...		0·66-0·69	0·70-0·73	0·74-0·77	0·78-0·81	0·82-0·85	0·86-0·89	0·90-0·93	0·94-0·97	0·98-1·01		
Mid-points of Length Class-intervals ...		0·675	0·715	0·755	0·795	0·835	0·875	0·915	0·955	0·995	Totals of Frequency rows	Mean lengths
Counts Class-intervals	Mid-points of Counts Class-intervals											
5- 8	6·5	5	3	—	—	—	—	—	—	—	8	0·690
9-12	10·5	—	2	3	1	—	—	—	—	—	6	0·748
13-16	14·5	—	—	5	4	2	—	—	—	—	11	0·784
17-20	18·5	—	—	—	4	—	—	—	—	—	4	0·795
21-24	22·5	—	—	—	5	7	—	—	—	—	12	0·818
25-28	26·5	—	—	1	1	4	2	2	—	—	10	0·847
29-32	30·5	—	—	—	—	2	6	6	3	1	18	0·904
33-36	34·5	—	—	—	—	1	9	5	1	—	16	0·890
37-40	38·5	—	—	—	1	—	2	1	4	—	8	0·910
41-44	42·5	—	—	—	—	—	—	1	—	1	2	0·955
Totals of Frequency-columns		5	5	9	16	16	19	15	8	2	95	—
Mean Counts		6·5	8·1	14·5	20·0	24·2	32·8	32·6	35·0	36·5	—	—

When the number of pairs of observations is at all large, the direct method of calculating the correlation coefficient becomes very laborious, and another method, depending on the grouping of the individual observations into definite classes, is used instead. And as this method throws further light on the correlation coefficient and its use in forecasting formulæ, its application to a simple case will now be explained. For this purpose reference may be made to Table I, in which are classified the results for the mean fibre-lengths and the corresponding highest standard warp counts for the 95 samples of Series I. It will be observed that each sample is classified for both properties at the same time, as the different columns represent different class-intervals of fibre-length, and the different rows represent different class-intervals of highest standard warp counts; and any particular entry in the table represents the number of samples falling in the class interval for fibre-length at the head of the column and also in the class-interval for highest standard warp counts at the left-hand side of the row. The total numbers of samples falling in the different "counts class-intervals" irrespective of their fibre-lengths, are shown in the second column from the right; the mean fibre-lengths for these several totals are given in the column on the extreme right. Similar results are shown in the two bottom rows for the total numbers of samples falling in the different "length class-intervals," and the corresponding mean counts for the several totals.

It will be noted that there are no entries falling in the top right and bottom left regions of Table I, and that all the entries fall, so to speak, near a line running from the top left to the bottom right-hand corner. This fact itself indicates that there is high correlation between fibre-length and the highest standard warp counts, short length being associated with low counts and greater length with higher counts. Moreover, as indicated on page T13, we may show these results graphically by plotting (1) the values of mean fibre-length (column 13) against the mid-points of the counts class-intervals (column 2); and (2) the values of mean counts (row 14) against the mid-points of the length class-intervals (row 2). If lines are drawn to join the plotted points, the line for (1) is the ***regression line*** of length on counts, and that for (2) is the ***regression line*** of counts on strength. Only in cases of perfect correlation are these lines coincident with one another. The lines are plotted in Fig. 1, from which it is again clear that the lines do nearly coincide, showing that the correlation between fibre-length and highest standard warp counts is very high. We may replace the lines joining the actual points by a single straight line for each regression line, drawn so as to give the best fit to the points. The equations to these straight lines of best fit are known as ***regression equations***; and if x_1 represents the average value of highest standard warp counts for a given value x_2 of fibre-length, the regression of highest standard warp counts on fibre-length is given by the regression equation

$$x_1 = r_{12}\frac{\sigma_1}{\sigma_2}\cdot x_2{}^* \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

as explained on page T13, when the highest standard warp counts and the fibre-lengths are measured from their mean values. Similarly the regression of fibre-length on highest standard warp counts is given by the regression equation

$$x_2 = r_{12}\cdot\frac{\sigma_2}{\sigma_1}\cdot x_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The coefficients $r_{12}\cdot\frac{\sigma_1}{\sigma_2}$ and $r_{12}\cdot\frac{\sigma_2}{\sigma_1}$ in regression equations (1) and (2) above, are known as ***regression coefficients***, as they respectively measure the regression of x_1 on x_2, and x_2 on x_1.

As the practical problem before us is the prediction of the highest standard warp counts from the fibre-properties, we shall obviously need only the regression equation (1) for this purpose.

One further point may be noted. The regression equations above apply when the highest standard warp counts and the fibre-lengths are measured from their ***mean*** values, i.e. x_1 and x_2 represent differences between the direct observational values and the respective mean values; thus if X_1 and X_2 are corresponding actual observational values, M_1 and M_2 the respective means, $x_1 = (X_1 - M_1)$, and $x_2 = (X_2 - M_2)$, so that the regression equation (1) may also be written

$$(X_1 - M_1) = r_{12}\cdot\frac{\sigma_1}{-}(X_2 - M_2)$$

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[*] This equation is really identical with the similar equation given on page T13. r_{12} here indicates the correlation between X_1 (i.e. property 1) and X_2 (i.e. property 2); the subscript "12" of r is therefore to be read as "one, two," not as "twelve."

In the case of the 95 samples of Series I, the average value of the highest standard warp counts, M_1, is 25, and the average value of all the fibre-lengths, M_2, is 0·84. Also, $r_{12} = 0{\cdot}87$, $\sigma_1 = 9{\cdot}7$, $\sigma_2 = 0{\cdot}078$.

$$\therefore (X_1 - 25) = 0{\cdot}87 \times \frac{9{\cdot}7}{0{\cdot}078} (X_2 - 0{\cdot}84)$$

$$\therefore X_1 = 108{\cdot}2\, X_2 - 65{\cdot}7.$$

By substituting any observed value of fibre-length on the right-hand side of this equation, we may calculate the corresponding predicted value for the highest standard warp count. Similar equations are given below for the prediction of highest standard warp counts from any one of the other measured fibre-properties, both for the samples of Series I and Series II. It should be noted that for the sake of simplicity and convenience in the subsequent treatment we shall frequently indicate the various properties merely by numerals, as follows—

1 = highest standard warp counts,
2 = fibre-length,
3 = fibre-weight per inch,
4 = fibre-width,
5 = fibre-strength,
6 = fibre-convolutions per inch,
7 = fibre-rigidity,
8 = fibre clinging-power.

Fibre-property	Regression Equation	
	Series I	Series II
2—Length (X_2)	$X_1 = 108{\cdot}2X_2 - 65{\cdot}7$	$X_1 = 96{\cdot}7X_2 - 55{\cdot}2$
3—Weight per inch (X_3)	$X_1 = 57{\cdot}2 - 164{\cdot}1X_3$	$X_1 = 56{\cdot}3 - 158{\cdot}1X_3$
4—Width (X_4)	$X_1 = 100{\cdot}9 - 111{\cdot}6X_4$	$X_1 = 107{\cdot}2 - 120X_4$
5—Strength (X_5)	$X_1 = 41{\cdot}9 - 106{\cdot}7X_5$	$X_1 = 39{\cdot}2 - 78X_5$
6—Convolutions (X_6)	$X_1 = 10{\cdot}3 + 0{\cdot}165X_6$	$X_1 = 12{\cdot}6 + 0{\cdot}162X_6$
7—Rigidity (X_7)	$X_1 = 36{\cdot}9 - 63{\cdot}1X_7$	$X_1 = 37{\cdot}0 - 61{\cdot}5X_7$
8—Clinging-power (X_8)	—	$X_1 = 66{\cdot}3 - 130{\cdot}7X_8$

1—Highest Standard Warp Counts (X_1).

It may be noted that the equations are very nearly the same for Series I and Series II, and may be taken as applying generally to Indian cottons. But, as already pointed out, they sometimes give very divergent results when used as forecasting formulæ. Further, some curious consequences of these equations may be noted, arising from the fact that as no fibre-property can have a negative value, its minimum value is evidently zero. In all those equations in which a negative sign precedes the term in which the value for the fibre-property is to be substituted, there is necessarily a maximum limit set to the highest standard warp counts, this maximum being the constant in the equation. It follows that these equations could not predict a higher standard warp count than 57 from fibre-weight (X_3), 101 from ribbon-width (X_4), 42 from fibre-strength (X_5), and 37 from fibre-rigidity (X_7).

We now proceed to the case when all the fibre-properties are taken into consideration at the same time. When n variables, say $X_1, X_2, X_3, \ldots X_n$ are considered, the correlation between X_1 and X_2 when the remaining variables $X_3, X_4, \ldots X_n$ are kept constant (or when changes in these variables are allowed for, so far as this may be done in a linear equation) is termed the ***partial correlation coefficient***, which is symbolically represented by $r_{12\cdot34\cdots n}$*.

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*This is merely a shorthand method of indicating the correlation between properties 1 and 2 when all the other properties, 3, 4, ... up to n remain constant; and just as the subscript of r_{12} is read as "one, two" (page T29, footnote) so the subscript of $r_{12\cdot34\ldots n}$ is read as "one, two, point three, four, ... upto n."

As indicated on page T14, the linear equation for predicting the highest standard warp counts from any number (n) of fibre-properties considered together is given by—

$$x_1 = b_2x_2 + b_3x_3 + \ldots + b_nx_n \qquad \ldots\ldots(3)$$

where $b_2, b_3, \ldots b_n$ are the *partial regression coefficients* (page T14), and $x_1, x_2, x_3, \ldots x_n$ are the values of the fibre-properties measured from their mean values, or, in other words, the deviations of the corresponding actual observational values $X_1, X_2, X_3, \ldots X_n$ from their respective arithmetic means. If any one of the coefficients, say b_2, has a positive value, it indicates that there is a positive correlation between X_1 and X_2 which is not affected by any correlation of X_1 and X_2 with $X_3, \ldots X_n$, as the effects of the changes in these properties are allowed for in the remaining terms of the right hand side of the equation. Moreover, the coefficient b_2 measures the mean change in X_1 for a unit change in X_2 when all the other properties remain constant; it is for this reason that b_2 is termed the partial regression coefficient of X_1 on X_2. There are various methods of determining the partial regression coefficients; as we are also interested to know the partial correlation coefficients, we have used first the method given by Yule[29] for this purpose, which entails the use of the partial correlation coefficients in the determination of the partial regression coefficients.

The regression equation can therefore be put in the form—

$$x_1 = b_{12\cdot34\ldots n}x_2 + b_{13\cdot24\ldots n}x_3 + \ldots\ldots + b_{1n\cdot23\ldots(n-1)}x_n \qquad \ldots\ldots(4)$$

where $b_{12\cdot34\ldots n}$ is the partial regression of x_1 on x_2, when all the properties are considered together, with similar meanings attached to the other coefficients.

It is shown in Yule's "Statistics"[30] that, if we choose the coefficients in equation (4) so as to make it one of best fit to the data, $b_{12\cdot34\ldots n}$ is given in terms of the partial correlation coefficient and the standard errors of estimate by the following equation—

$$b_{12\cdot34\ldots n} = r_{12\cdot34\ldots n}\,\frac{\sigma_{1\cdot34\ldots n}}{\sigma_{2\cdot34\ldots n}} \qquad \ldots\ldots(5)$$

$r_{12\cdot34\ldots n}$ is called the partial correlation coefficient of the $(n-2)$th order, since it has $(n-2)$ secondary subscripts, i.e. subscripts after the point; thus, as r_{12} has no secondary subscripts, it can be termed a partial correlation coefficient of zero order, which is thus identical with the total correlation coefficient. Relations similar to (5) hold for the coefficients of $x_3, x_4, \ldots\ldots x_n$, in equation (4).

It is also shown in Yule's "Statistics"[31] that the following equation connects partial correlation coefficients of different orders, and so enables the partial correlation coefficient of any particular order $(n-2)$, to be calculated from partial correlation coefficients of the next lower $(n-3)$th order—

$$r_{12\cdot34\ldots n} = \frac{r_{12\cdot34\ldots(n-1)} - r_{1n\cdot34\ldots(n-1)}\cdot r_{2n\cdot34\ldots(n-1)}}{\left(1-r^2_{1n\cdot34\ldots(n-1)}\right)^{\frac{1}{2}}\left(1-r^2_{2n\cdot34\ldots(n-1)}\right)^{\frac{1}{2}}} \qquad \ldots\ldots(6)$$

The partial correlation coefficient of $(n-3)$th order may be obtained from those of $(n-4)$th order by a similar equation, and so on, so that ultimately the partial correlation coefficients of the highest $(n-2)$th order may be connected with those of the lowest, i.e. zero order.

Reference has been made above to the standard errors of estimate; these also may be calculated from the standard deviations of the original observations and from the partial correlation coefficients by means of equations of the following type[32]—

$$\sigma^2_{1\cdot 23\,.\,.\,.\,n}=\sigma^2_1(1-r^2_{12})(1-r^2_{13\cdot 2})(1-r^2_{14\cdot 23})\ldots(1-r^2_{1n\cdot 23\ldots\ldots(n-1)}) \quad\ldots\ldots(7)$$

Hence, by using the total correlation coefficients we may calculate the partial correlation coefficients of higher order in succession, and use these as required for determining the standard errors of estimate by the application of equation (7), and finally determine the partial regression coefficients by the application of equation (5).

The application of these formulæ is illustrated by the following example giving the steps in the solution of the problem of predicting the highest standard warp counts from the seven fibre-properties of Series II, represented as before by the numerals 2, 3, 4, 5, 6, 7, 8, the highest standard warp count itself being represented by the numeral 1.

In the first place, the regression equation itself becomes, for $n=8$ in equation (4), page T31—

$$x_1=b_{12\cdot 345678}x_2+b_{13\cdot 245678}x_3+\ldots\ldots+b_{17\cdot 234568}x_7+b_{18\cdot 234567}x_8 \quad\ldots\ldots\ldots\ldots(8)$$

The partial regression coefficients are obtained from type-equation (5), page T31, as follows—

$$b_{12\cdot 345678}=r_{12\cdot 345678}\frac{\sigma_{1\cdot 345678}}{\sigma_{2\cdot 345678}} \quad\ldots\ldots\ldots\ldots(9)$$

$$b_{13\cdot 245678}=r_{13\cdot 245678}\frac{\sigma_{1\cdot 245678}}{\sigma_{3\cdot 245678}} \quad\ldots\ldots\ldots\ldots(10)$$

……………………………………………………………………

$$b_{17\cdot 234568}=r_{17\cdot 234568}\frac{\sigma_{1\cdot 234568}}{\sigma_{7\cdot 234568}} \quad\ldots\ldots\ldots\ldots(11)$$

$$b_{18\cdot 234567}=r_{18\cdot 234567}\frac{\sigma_{1\cdot 234567}}{\sigma_{8\cdot 234567}} \quad\ldots\ldots\ldots\ldots(12)$$

The partial correlation coefficients of the sixth order in equations (9) to (12) are evaluated by repeated application of the type-equations (6), thus the partial correlation coefficient of equation (9)—

$$r_{12\cdot 345678}=\frac{r_{12\cdot 34567}-r_{18\cdot 34567}\cdot r_{28\cdot 34567}}{(1-r^2_{18\cdot 34567})^{\frac{1}{2}}(1-r^2_{28\cdot 34567})^{\frac{1}{2}}} \quad\ldots\ldots\ldots\ldots(13)$$

and repeated application of type-equation (6) similarly enables the partial correlation coefficients of fifth order in type-equation (13) to be expressed in terms of partial correlation coefficients of fourth order, thus

$r_{12\cdot 34567}$ is expressed in terms of $r_{12\cdot 3456}$, $r_{17\cdot 3456}$, and $r_{27\cdot 3456}$
$r_{18\cdot 34567}$,, ,, $r_{18\cdot 3456}$, $r_{17\cdot 3456}$, and $r_{87\cdot 3456}$
$r_{28\cdot 34567}$,, ,, $r_{28\cdot 3456}$, $r_{27\cdot 3456}$, and $r_{87\cdot 3456}$

These fourth order partial correlation coefficients are similarly derived from third order partial correlation coefficients, the third order similarly from the second, the second order similarly from the first, and finally the first order from the zero order or total correlations. By working backwards in this way it is possible to pick out (and evaluate) just those partial correlation coefficients of each order that are ultimately necessary for the evaluation of the seven partial correlation coefficients of the sixth order appearing in equations (9) to (12).

The values of the σ's in equations (9) to (12) for the partial regression coefficients, are determined by the application of type-equation (7), page T32, from which we get

$$\sigma_{1\cdot345678} = \sigma_1(1-r^2_{13})^{\frac{1}{2}}(1-r^2_{14\cdot3})^{\frac{1}{2}}(1-r^2_{15\cdot34})^{\frac{1}{2}}(1-r^2_{16\cdot345})^{\frac{1}{2}}(1-r^2_{17\cdot3456})^{\frac{1}{2}}(1-r^2_{18\cdot34567})^{\frac{1}{2}}$$

$$\sigma_{2\cdot345678} = \sigma_2(1-r^2_{23})^{\frac{1}{2}}(1-r^2_{24\cdot3})^{\frac{1}{2}}(1-r^2_{25\cdot34})^{\frac{1}{2}}(1-r^2_{26\cdot345})^{\frac{1}{2}}(1-r^2_{27\cdot3456})^{\frac{1}{2}}(1-r^2_{28\cdot34567})^{\frac{1}{2}}$$

$$\sigma_{3\cdot245678} = \sigma_3(1-r^2_{32})^{\frac{1}{2}}(1-r^2_{34\cdot2})^{\frac{1}{2}}(1-r^2_{35\cdot24})^{\frac{1}{2}}(1-r^2_{36\cdot245})^{\frac{1}{2}}(1-r^2_{37\cdot2456})^{\frac{1}{2}}(1-r^2_{38\cdot24567})^{\frac{1}{2}}$$

$$\sigma_{7\cdot234568} = \sigma_7(1-r^2_{72})^{\frac{1}{2}}(1-r^2_{73\cdot2})^{\frac{1}{2}}(1-r^2_{74\cdot23})^{\frac{1}{2}}(1-r^2_{75\cdot234})^{\frac{1}{2}}(1-r^2_{76\cdot2345})^{\frac{1}{2}}(1-r^2_{78\cdot23456})^{\frac{1}{2}}$$

$$\sigma_{8\cdot234567} = \sigma_8(1-r^2_{82})^{\frac{1}{2}}(1-r^2_{83\cdot2})^{\frac{1}{2}}(1-r^2_{84\cdot23})^{\frac{1}{2}}(1-r^2_{85\cdot234})^{\frac{1}{2}}(1-r^2_{86\cdot2345})^{\frac{1}{2}}(1-r^2_{87\cdot23456})^{\frac{1}{2}}$$

The values of the different partial correlation coefficients that have been evaluated from the 45 sets of values of the fibre-properties of the Series II samples, in order to obtain the values of the seven regression coefficients of equation (8), are given in Appendix V, Table II. Similarly, Table I of Appendix V gives the values of the partial correlation coefficients evaluated from the 95 sets of values of the fibre-properties of Series I and used in obtaining the six partial regression coefficients necessary for the corresponding regression equation of this series.

The two regression equations thus obtained are, in terms of deviations from the respective means—

For Series I: $x_1 = 71{\cdot}6x_2 - 70{\cdot}8x_3 - 20{\cdot}8x_4 + 17{\cdot}9x_5 + 0{\cdot}037x_6 + 4{\cdot}4x_7$.

For Series II: $x_1 = 42{\cdot}7x_2 - 66{\cdot}4x_3 - 49{\cdot}3x_4 - 18{\cdot}7x_5 + 0{\cdot}0277x_6 + 21{\cdot}8x_7 - 26{\cdot}2x_8$

When the actual observational values (X_1, X_2, X_3, X_4,.........X_8) for the fibre-properties are used for direct substitution in the regression equations, as on page T15, these become

For Series I:

$$X_1 = 71{\cdot}6X_2 - 70{\cdot}8X_3 - 20{\cdot}8X_4 + 17{\cdot}9X_5 + 0{\cdot}037X_6 + 4{\cdot}4X_7 - 14{\cdot}1 \quad \text{.........}(14)$$

For Series II:

$$X_1 = 42{\cdot}7X_2 - 66{\cdot}4X_3 - 49{\cdot}3X_4 - 18{\cdot}7X_5 + 0{\cdot}0277X_6 + 21{\cdot}8X_7 - 26{\cdot}2X_8 + 39{\cdot}5 \quad (15)$$

Similar regression equations were calculated omitting from consideration some of the measured fibre-properties; these equations were

For counts (X_1), fibre-length (X_2), and fibre-weight per inch (X_3)—

Series I: $X_1 = 75{\cdot}4[\pm10{\cdot}8]X_2 - 79{\cdot}5[\pm14{\cdot}8]X_3 - 22{\cdot}8$ .... (16)

Series II: $X_1 = 54{\cdot}8X_2 - 110{\cdot}9X_3 + 0{\cdot}7$...(17)

For counts (X_1), fibre-length (X_2), fibre-weight per inch (X_3), and fibre-strength (X_5)—

Series I: $X_1 = 72{\cdot}5[\pm10{\cdot}7]X_2 - 93{\cdot}3[\pm17{\cdot}9]X_3 + 26{\cdot}7[\pm17{\cdot}8]X_5 - 21{\cdot}8$ (18)

For counts (X_1), fibre-length (X_2), fibre-weight per inch (X_3), and ribbon-width (X_4)—

Series I: $X_1 = 72{\cdot}2X_2 - 61{\cdot}9X_3 - 23{\cdot}9X_4 - 7{\cdot}2$ ....(19)

For counts (X_1), fibre-length (X_2), fibre-weight per inch (X_3), ribbon-width (X_4), and clinging-power (X_8)—

Series II: $X_1 = 48{\cdot}6X_2 - 58{\cdot}3X_3 - 50{\cdot}1X_4 - 35{\cdot}4X_8 + 40{\cdot}1$ ....(20)

The spinning-values predicted for the various cottons by these different formulæ are shown in Appendix IV. The extent to which the predicted values agree with the actual spinning-values has already been discussed on pages T23 and T24.

As mentioned on page T22, in order to test the statistical significance of the partial regression coefficients in the prediction formula for Series I, the standard errors of these coefficients were calculated; the standard errors of the partial regression coefficients of equation (14)—the complete equation for Series I—have already been discussed (page T22). The formula[33] for calculating the standard error of a partial regression coefficient $b_{12\cdot k}$ for a normal distribution is $\frac{\sigma_{1\cdot 2k}}{\sigma_{2\cdot k}\sqrt{n}}$[*], where *k* denotes any collection of secondary subscripts other than 1 or 2. For example, the coefficient of X_2 in equation (4) applied to Series I is $b_{12\cdot 34567}$, so that its standard error is $\frac{\sigma_{1\cdot 234567}}{\sigma_{2\cdot 34567}\sqrt{n}}$, the value of which is obtained by applying type-equation (7).

The standard errors of the partial regression coefficients have also been calculated for the prediction equations (16) and (18) relating to the Series I samples; in these cases the standard errors are shown in brackets immediately following the partial regression coefficients to which they relate. It will be observed that in equation (16) the partial regression coefficients of fibre-length (X_2) and fibre-weight per inch (X_3) are respectively 7·0 and 5·4 times as large as their standard errors, so that both coefficients are statistically significant. The same is true for the partial regression coefficients of these properties in equation (18), but in this case the additional term for fibre-strength (X_5) has a partial regression coefficient which is only 1·5 times its standard error, and so is not statistically significant, even if we only apply our less stringent test of significance that the coefficient must be at least twice as large as its standard error (page T22).

It is interesting to note that the partial regression coefficient for fibre-strength (X_5) is positive in equation (14) Series I), and negative in equation (15) (Series II), as a consequence of the corresponding partial correlation coefficients being respectively positive and negative. Reference to Appendix V shows that the total correlation coefficients between highest standard warp counts and fibre-strength are both negative; the first order coefficients, eliminating fibre-length, are likewise both negative; but the second order coefficients, eliminating also fibre-weight per inch, are both positive; when ribbon-width and convolutions are also eliminated, the coefficients remain positive; but whereas the elimination also of fibre-rigidity leaves the fifth order coefficient still positive in Series I, it causes the coefficient in Series II to become negative, and to remain so for the sixth order coefficient with clinging-power also eliminated. At the same time it should be remarked that none of these partial correlation coefficients for fibre-strength which are of higher order than the first can be regarded as statistically significant (page T22).

In only one other case is the sign of the partial regression coefficient opposite to that of the corresponding *total* correlation coefficient, viz. for the fibre-rigidity (X_7), which, for both Series I and Series II, has negative total correlation coefficients but positive partial regression coefficients in equations

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[*] In applying this formula n has been taken as $(n'-p-1)$, where $n'=$ the number of sets of observations and $p=$ the number of independent variables, so that for the Series I samples, where $n'=95$, $p=6$, we have $n=88$.

(14) and (15). The change occurs when the fibre-weight per inch is eliminated, resulting in the second and all higher order partial correlation coefficients being negative—the change arising partly from the strong positive correlation between fibre-rigidity and fibre-weight per inch.

It was stated on page T31 that the partial regression coefficients in equation (4) are so chosen as to make it one of best fit to the data. The method used for doing this is technically known as the "Method of Least Squares" because the test adopted of "best fit" is that the sum of the squares of the differences between the observed values of X_1 and those calculated from the right-hand side of the regression equation, shall be a minimum. Now the method already described for determining the values of the coefficients of the regression equation necessitates very heavy arithmetical work, chiefly in the calculation of the partial correlation coefficients. These partial correlation coefficients have an intrinsic interest in the present case, and have already been discussed. But shorter methods, also based on the "Method of Least Squares" but not necessitating the calculation of the partial correlation coefficients, are available for the calculation of the partial regression coefficients of the prediction formula, and these methods have therefore been employed as a check.

The first check method is that given by Kelley,[34] who gives the generalised regression equation (4) in terms of the variables themselves—as in equation (14)—instead of in terms of the deviations, as in equation (4). This generalised equation is—

$$X_1 = b_{12\cdot34\ldots n}X_2 + b_{13\cdot24\ldots n}X_3 + \ldots + b_{1n\cdot23\ldots(n-1)}X_n + C \quad \ldots\ldots\ldots\ldots(21)$$

Instead of expressing the partial regression coefficients in terms of the partial correlation coefficients, Kelley has introduced a series of "beta" coefficients which are in effect defined by the following relation[35]—

$$b_{12\cdot34\ldots n} = \beta_{12\cdot34\ldots n}\frac{\sigma_1}{\sigma_2} \text{ etc.} \quad \ldots\ldots\ldots\ldots(22)$$

In equation (21)

$$C = M_1 - b_{12\cdot34\ldots n}M_2 - b_{13\cdot24\ldots n}M_3 - \ldots - b_{1n\cdot23\ldots(n-1)}M_n \quad \ldots\ldots\ldots\ldots(23)$$

where M_1, M_2, M_3, M_n are the mean-values of the several variables X_1, X_2, X_3, ...X_n. A β of any order, $\beta_{12\cdot34\ldots n}$, can be connected with a β of lower order by means of the relation[36]—

$$\beta_{12\cdot34\ldots n} = \frac{\beta_{12\cdot4\ldots n} - \beta_{13\cdot4\ldots n}\,\beta_{32\cdot4\ldots n}}{1 - \beta_{23\cdot4\ldots n}\,\beta_{32\cdot4\ldots n}} \quad \ldots\ldots\ldots\ldots(24)$$

the β's on the right-hand side being connected with β's of still lower order by repeated application of the same relation, until all the β's are connected with β's of the first order. The β's of the first order are calculated from the total correlation coefficients by means of the relation[37]—

$$\beta_{12\cdot3} = \frac{r_{12} - r_{13}r_{23}}{1 - r^2_{23}} \quad \ldots\ldots\ldots\ldots(25)$$

Having obtained the values of all the β's by the application of equations (24) and (25), we obtain the values of the partial regression coefficients by the application of equation (22), and thence the value of C from equation (23). As already indicated, the arithmetical work by this method is decidedly less than by the previous method.

The second check method[38] is still less onerous in its arithmetical demands. If we take the regression equation (3) as for six fibre-properties (Series I)

$$x_1 = b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6+b_7x_7 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

the problem is to determine the best values of the six unknown constants b_2, b_3, ... b_7. This could be done if we had six sets of values of x_1, x_2, ... x_7, for we could them form six simultaneous equations which would be just sufficient for the complete solution of the equations, i.e. for the determination of b_2, b_3, ... b_7. Actually, however, in the case of the Series I samples we have 95 sets of values of x_1, x_2, ... x_7 available, from which we could make 95 equations to find the b's; we could of course choose six sets out of these 95 sets in many different ways, and the various selections of six sets would lead to different sets of values for the b's. As there is no justification for arbitrarily taking any particular selection of six sets, what is done in practice is to apply the "Method of Least Squares" to reduce the 95 equations to six, yet using all the data provided by the 95; these six equations so obtained are called the "normal equations"; by solving these equations the best values are obtained for the constants b_2, b_3, ... b_7 of the regression equation. These normal equations are as follows—

$$\left.\begin{array}{l}
b_2\Sigma x^2{}_2+b_3\Sigma x_2x_3+\ldots\ldots+b_7\Sigma x_2x_7=\Sigma x_1x_2 \\
b_2\Sigma x_2x_3+b_3\Sigma x^2{}_3+\ldots\ldots+b_7\Sigma x_3x_7=\Sigma x_1x_3 \\
\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
b_2\Sigma x_2x_6+b_3\Sigma x_3x_6+\ldots\ldots+b_7\Sigma x_6x_7 = \Sigma x_1x_6 \\
b_2\Sigma x_2x_7+b_3\Sigma x_3x_7+\ldots\ldots+b_7\Sigma x^2{}_7 = \Sigma x_1x_7
\end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (26)$$

The method is of course perfectly general for any number of variables. Special methods for the solution of the normal equations are given in works on "Statistics".[38]

It may be noted that when the partial regression coefficients are calculated by this method, it is possible to utilise new data by combining it with the old data without the necessity of repeating all the arithmetical work.[39]

As previously mentioned, all three methods have been applied to the data of Series I and II, and all have led to the same regression equations to be used as prediction-formulæ.

Coefficient of Multiple Correlation—The partial correlation coefficients show how the highest standard warp count is correlated with each of the different fibre-properties separately, with the effect of any correlation between the other fibre-properties eliminated. Another useful statistical measure indicates the degree to which variations in the dependent variable (highest standard warp count) are related to the combined effect of the independent variables (fibre-properties); this statistical measure is known as the *coefficient of multiple correlation*, and is defined by the equation[40]—

$$R^2_{1\cdot 23\ldots n} = 1 - \frac{\sigma^2{}_{1\cdot 23\ldots n}}{\sigma^2_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

where $R_{1\cdot 23\ldots n}$ is the multiple correlation coefficient of the dependent variable 1 and the independent variables 2, 3,...n. The σ's have the same significance as in equation (7). The coefficient of multiple correlation can be expressed by the following equation purely in terms of the partial correlation coefficients when the first method is employed for calculating the regression equation[41]—

$$1-R^2_{1\cdot 23\ldots n}=(1-r^2_{12})(1-r^2_{13\cdot 2})(1-r^2_{14\cdot 23})\ldots(1-r^2_{1n\cdot 23\ldots(n-1)})\ldots\ldots(28)$$

and by the following equation when the third method is employed[42]—

$$R^2_{1\cdot 23\ldots n}=\frac{\{b_{12\cdot 34\ldots n}(\Sigma x_1x_2)+b_{13\cdot 24\ldots n}(\Sigma x_1x_3)+\ldots+b_{1n\cdot 23\ldots(n-1)}(\Sigma x_1x_n)\}}{\Sigma(x_1^2)}\quad(29)$$

In the case of the present series of tests, the coefficient of multiple correlation for the highest standard warp counts was found to be—

0·93 for Series I (six fibre-properties),
0·91 for Series II (seven fibre-properties).

As the value of R^2 is a measure of how far the independent variables account for the value of the dependent variable,[43] in the case of Series I we have $R^2=0{\cdot}86$, so that 86% of the variation in spinning-value is accounted for by the six measured fibre-properties, leaving 14% to be accounted for otherwise.

APPENDIX II

A Short Method for Revising the Total Correlation Coefficients to Include Further Results Obtained in Successive Seasons

In the table on page T18 are given the total correlation coefficients between the highest standard warp counts for five successive seasons, the test-results for each successive season being included as they became available. Now where the number of pairs of observational values is comparatively large, the working out of a single total correlation coefficient necessitates a good deal of arithmetical labour in applying the simple formula—

$$r=\frac{\Sigma xy}{N\sigma_x\sigma_y}=\frac{\Sigma xy}{\sqrt{(\Sigma x^2\cdot\Sigma y^2)}}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(30)$$

where x, y are deviations of a corresponding pair of observational values X, Y from their respective means, M_x, M_y. Thus in applying this formula to all the 134 samples included up to 1931-32, we have to determine—

(i) the mean values of the 134 values of each property;
(ii) the deviation of each of the 134 observational values from its corresponding mean;
(iii) the square of each of the 134 deviations for each property;
(iv) the sum of the 134 squares of the deviations for each property;
(v) the product (xy) of the deviation of each fibre-property with the corresponding deviation of highest standard warp counts;
(vi) the algebraic sum (Σxy) of the 134 products (v) for each fibre-property;
(vii) the value of r as given by equation (30) from (iv) and (vi) for each fibre-property.

The arithmetical labour for 134 samples and seven properties is evidently considerable, especially if it all has to be done *ab initio* every season—and this at first sight would appear to be necessary because the new data every season cause changes in the values of the means and consequently in the deviations of the observational values of the preceding seasons from these means. As the heavy labour is due primarily to the changes in the values of the means, it may be avoided by adopting, once for all, at the beginning, an arbitrary mean for each property, and later making the proper corrections necessitated by this procedure.

Let A_x be the arbitrary means adopted for a fibre-property,
and A_y „ „ „ the highest standard warp counts.

Suppose that the total correlation coefficient has been obtained for m pairs of observational values $(X_1, Y_1; X_2, Y_2; \ldots\ldots X_m, Y_m)$ and that it is desired to find the new total correlation coefficient when n new pairs of observational values $(X'_1, Y'_1; X'_2, Y'_2; \ldots\ldots X'_n, Y'_n)$ are available, i.e. for $(m+n)$ pairs of observational values in all.

The means for the m original values are given by—

$$M_x = \frac{\Sigma X}{m} \ ; \ M_y = \frac{\Sigma Y}{m} \qquad \ldots\ldots\ldots\ldots (31)$$

The new means, with n additional values, are written M'_x, M'_y, and are given by—

$$M'_x = \frac{\Sigma X + \Sigma X'}{m+n} \ ; \ M'_y = \frac{\Sigma Y + \Sigma Y'}{m+n} \qquad \ldots\ldots\ldots\ldots (32)$$

As ΣX and ΣY have already been found in order to determine the original mean-values by (31), the solution of equations (32) merely necessitates finding the sum of the new values only, then adding the result to the sum of the old values, and dividing the result by $(m+n)$. Thus if we already have the sum of the values for any property of the 116 samples of 1930-31, we have only to add to it the sum of the values for the new 18 samples of 1931-32, and divide by 134, in order to get the new mean-value for the property.

The steps (ii) to (vii) which are necessary in obtaining the original values of the total correlations by equation (30) may be indicated by re-writing that equation in terms of the mean-values and the original observational values, so that—

$$r = \frac{\Sigma(X-M_x)(Y-M_y)}{\sqrt{\{\Sigma(X-M_x)^2 \cdot \Sigma(Y-M_y)^2\}}} \qquad \ldots\ldots\ldots\ldots (33)$$

But if arbitrary means A_x and A_y are used instead of the real means in steps (ii) to (vii)—as is usually done in practice—certain corrections become necessary, and these are indicated by re-writing (33) in terms of the arbitrary means, thus—

$$r = \frac{\Sigma^m{}_1(X-A_x)(Y-A_y) - m(A_x-M_x)(A_y-M_y)}{\sqrt{[\{\Sigma^m{}_1(X-A_x)^2 - m(A_x-M_x)^2\}\{\Sigma_1{}^m(Y-A_y)^2 - m(A_y-M_y)^2\}]}} \qquad (34)$$

In (34) the correction terms are $m(A_x-M_x)(A_y-M_y)$ in the top line, and $m(A_x-M_x)^2$ and $m(A_y-M_y)^2$ in the bottom line, all of which are easy to calculate.

When we include the n new pairs of values, the new value of r is given by—

$$r = [\Sigma_1{}^m(X-A_x)(Y-A_y) + \Sigma_1{}^n(X'-A_x)(Y'-A_y) - (m+n)(A_x-M'_x)(A_y-M'_y)]$$
$$\div \sqrt{[\{\Sigma_1{}^m(X-A_x)^2 + \Sigma_1{}^n(X'-A_x)^2 - (m+n)(A_x-M'_x)^2\} \times}$$
$$\overline{\{\Sigma_1{}^m(Y-A_y)^2 + \Sigma_1{}^n(Y'-A_y)^2 - (m+n)(A_y-M_y')^2\}]} \qquad \ldots\ldots\ldots\ldots (35)$$

In equation (35), $\Sigma_1{}^m(X-A_x)(Y-A_y)$, $\Sigma_1{}^m(X-A_x)^2$, and $\Sigma_1{}^m(Y-A_y)^2$ have already been found in order to obtain the previous value of r by (34); and it is these terms that are the most troublesome to evaluate as they are concerned with a comparatively large number of values; and if there are only few additional pairs of values (i.e. n is small), the remaining terms of equation (35) are obtained comparatively quickly, as the arithmetic is practically confined to dealing with the new values only.

APPENDIX III

Table I—Fibre-Properties of Series I Samples

Cotton	Season	Highest Standard Warp Counts	Length (inch)	Weight per inch (10^{-6} oz.)	Ribbon-Width (10^{-3} in.)	Strength (oz.)	Convolutions per inch	Rigidity (oz. in.$^2 \times 10^{-6}$)
Dharwar 1	1926–27	34	0·89	0·204	0·61	0·168	67	0·109
	1927–28	32	0·89	0·202	0·65	0·152	76	0·132
	1928–29	34	0·87	0·182	0·61	0·129	81	0·128
	1929–30	30	0·87	0·209	0·71	0·162	88	0·141
Jayawant	1929–30	32	0·91	0·224	0·72	0·192	78	0·238
Gadag 1	1923–24	36	0·89	0·174	0·70	0·138	130	0·203
	1924–25	20	0·81	0·154	0·67	0·125	132	0·137
	1925–26	30	0·82	0·150	0·71	0·107	134	0·149
	1926–27	38	0·81	0·179	0·63	0·141	110	0·151
	1927–28	38	0·86	0·167	0·62	0·148	115	0·152
	1928–29	26	0·82	0·162	0·59	0·141	122	0·138
	1929–30	32	0·84	0·166	0·64	0·140	140	0·157
1027 A.L.F.	1926–27	32	0·97	0·200	0·73	0·171	96	0·162
	1927–28	30	0·94	0·207	0·74	0·167	73	0·132
	1928–29	32	0·96	0·204	0·71	0·165	63	0·125
	1929–30	34	0·97	0·186	0·74	0·171	45	0·157
Wagad 4	1925–26	14	0·81	0·253	0·71	0·148	61	0·223
	1926–27	16	0·85	0·257	0·68	0·179	46	0·189
	1927–28	18	0·79	0·181	0·70	0·109	47	0·101
	1928–29	16	0·84	0·216	0·77	0·138	56	0·174
Wagad 8	1925–26	12	0·79	0·258	0·71	0·142	63	0·162
	1926–27	14	0·80	0·264	0·72	0·178	45	0·221
	1927–28	15	0·77	0·189	0·72	0·124	46	0·122
	1928–29	15	0·80	0·239	0·76	0·144	58	0·135
	1929–30	12	0·75	0·208	0·77	0·133	56	0·139
P.A. 4F	1926–27	24	0·78	0·134	0·70	0·132	104	0·093
	1927–28	22	0·79	0·186	0·70	0·156	102	0·210
	1928–29	16	0·76	0·197	0·68	0·169	99	0·234
	1929–30	20	0·81	0·179	0·69	0·167	107	0·215
P.A. 285F	1923–24	34	0·92	0·123	0·67	0·131	145	0·057
	1924–25	34	0·92	0·152	0·73	0·138	140	0·094
	1925–26	28	0·93	0·155	0·69	0·149	134	0·134
	1926–27	34	0·82	0·104	0·64	0·115	100	0·059
	1927–28	34	0·89	0·133	0·59	0·131	110	0·104
	1928–29	34	0·88	0·125	0·67	0·108	90	0·099
	1929–30	42	0·92	0·158	0·65	0·162	122	0·166
P.A. 289F	1926–27	38	0·97	0·098	0·62	0·109	88	0·053
	1927–28	40	0·94	0·142	0·62	0·135	118	0·092
	1928–29	38	0·96	0·122	0·58	0·151	122	0·093
	1929–30	42	1·00	0·147	0·61	0·148	145	0·101
Mollisoni	1926–27	8	0·68	0·272	0·77	0·164	65	0·242
	1927–28	8	0·73	0·335	0·88	0·195	114	0·463
	1928–29	7	0·69	0·303	0·76	0·182	106	0·512
	1929–30	8	0·69	0·298	0·81	0·167	87	0·386
Aligarh A. 19	1926–27	7	0·66	0·301	0·79	0·187	80	0·361
	1927–28	7	0·70	0·305	0·82	0·199	72	0·450
	1928–29	7	0·71	0·324	0·74	0·225	67	0·641
	1929–30	7	0·68	0·319	0·78	0·210	74	0·506
Cawnpore K. 22	1926–27	12	0·73	0·240	0·71	0·178	72	0·280
	1927–28	12	0·75	0·244	0·78	0·174	70	0·376
	1928–29	14	0·78	0·225	0·68	0·166	71	0·257
	1929–30	11	0·70	0·229	0·68	0·171	78	0·392
J.N. 1	1926–27	14	0·77	0·242	0·71	0·183	65	0·216
	1927–28	14	0·74	0·226	0·71	0·199	74	0·245
	1928–29	13	0·76	0·236	0·72	0·204	85	0·280
	1929–30	12	0·75	0·237	0·71	0·185	81	0·300

APPENDIX III—*continued*

Table I—Fibre-Properties of Series I Samples

Cotton	Season	Highest Standard Warp Counts	Length (inch)	Weight per inch (10^{-6} oz.)	Ribbon-Width (10^{-3} in.)	Strength (oz.)	Convolutions per inch	Rigidity (oz. in.^{2} × 10^{-4})
C.A. 9	1926–27	34	0·87	0·182	0·61	0·160	119	0·185
	1927–28	30	0·86	0·176	0·63	0·151	105	0·170
	1928–29	40	0·89	0·166	0·60	0·158	127	0·239
	1929–30	34	0·87	0·174	0·64	0·168	108	0·294
Verum Akola	1928–29	23	0·83	0·187	0·63	0·174	79	0·136
	1929–30	21	0·84	0·195	0·63	0·171	88	0·202
Verum Nagpur	1928–29	26	0·85	0·215	0·62	0·199	72	0·193
	1929–30	21	0·81	0·190	0·64	0·175	92	0·218
Umri Bani	1926–27	24	0·81	0·200	0·67	0·186	65	0·160
	1927–28	24	0·81	0·192	0·63	0·179	93	0·188
	1928–29	22	0·83	0·185	0·63	0·176	88	0·196
	1929–30	27	0·81	0·172	0·64	0·171	90	0·185
Cambodia Co. 1	1923–24	32	0·91	0·171	0·69	0·134	91	0·154
	1924–25	30	0·86	0·147	0·64	0·123	91	0·093
	1925–26	32	0·91	0·156	0·63	0·114	97	0·132
	1926–27	38	0·92	0·155	0·59	0·127	91	0·124
	1927–28	34	0·93	0·164	0·60	0·138	110	0·134
	1928–29	32	0·93	0·170	0·62	0·125	126	0·179
	1929–30	34	0·89	0·175	0·70	0·143	121	0·176
Cambodia Co. 2	1927–28	33	0·88	0·141	0·62	0·123	108	0·138
	1928–29	26	0·92	0·148	0·61	0·099	90	0·099
	1929–30	28	0·89	0·172	0·64	0·123	116	0·224
Nandyal 14	1926–27	34	0·93	0·191	0·61	0·223	46	0·142
	1927–28	31	0·88	0·196	0·67	0·229	56	0·147
	1928–29	31	0·91	0·187	0·65	0·236	60	0·169
	1929–30	35	0·91	0·190	0·65	0·232	70	0·169
Hagari 1	1928–29	24	0·84	0·207	0·65	0·140	78	0·164
	1929–30	27	0·84	0·192	0·71	0·128	88	0·129
Hagari 25	1926–27	26	0·76	0·177	0·65	0·110	54	0·097
	1927–28	26	0·87	0·205	0·70	0·135	76	0·112
	1928–29	30	0·90	0·188	0·65	0·132	75	0·098
	1929–30	25	0·85	0·208	0·66	0·136	63	0·128
Karunganni C7	1926–27	24	0·85	0·192	0·65	0·183	57	0·170
	1927–28	24	0·85	0·183	0·62	0·177	62	0·156
	1928–29	20	0·81	0·186	0·70	0·159	74	0·184
	1929–30	23	0·83	0·196	0·78	0·171	50	0·215
Mississippi	1923–24	30	0·99	0·183	0·65	0·180	142	0·138
Memphis	1925–26	40	0·95	0·181	0·62	0·154	110	0·146
Texas	1925–26	30	0·86	0·206	0·58	0·164	140	0·210
Mean	—	25	0·84	0·196	0·68	0·158	89	0·189

APPENDIX III—*continued*

Table II—Fibre Properties of Series II Samples

Cotton	Season	Highest Standard Warp Counts	Length (inch)	Weight per inch (10^{-6} oz.)	Ribbon Width (10^{-3} in.)	Strength (oz.)	Convolutions per inch	Rigidity (oz. in.$^2 \times 10^{-6}$)	Clinging power (oz.)
Gadag 1	†1923–24	36	0·87	0·174	0·70	0·138	130	0·203	0·269
	†1924–25	20	0·80	0·154	0·67	0·125	132	0·137	0·249
	1925–26	30	0·82	0·150	0·71	0·107	134	0·149	0·255
	1926–27	38	0·81	0·179	0·63	0·141	110	0·151	0·280
	A1927–28	38	0·86	0·167	0·62	0·148	115	0·152	0·241
	*B1927–28	24	0·81	0·182	0·65	0·163	104	0·178	0·256
	*C1927–28	32	0·83	0·164	0·68	0·134	124	0·177	0·258
	1928–29	26	0·82	0·162	0·59	0·141	122	0·138	0·306
Wagad 4	†1925–26	14	0·80	0·253	0·71	0·148	61	0·223	0·393
	1926–27	16	0·85	0·257	0·68	0·179	46	0·189	0·350
	1927–28	18	0·79	0·181	0·70	0·109	47	0·101	0·310
	1928–29	16	0·84	0·216	0·77	0·138	56	0·174	0·335
Wagad 8	†1925–26	12	0·78	0·258	0·71	0·142	63	0·162	0·419
	1926–27	14	0·80	0·264	0·72	0·178	45	0·221	0·339
	1927–28	15	0·77	0·189	0·72	0·124	46	0·122	0·284
	1928–29	15	0·80	0·239	0·76	0·144	58	0·135	0·403
P.A. 285F	†1923–24	34	0·93	0·123	0·67	0·131	145	0·057	0·260
	1924–25	34	0·92	0·152	0·73	0·138	140	0·094	0·270
	†1925–26	28	0·95	0·155	0·69	0·149	134	0·134	0·296
	1926–27	34	0·82	0·104	0·64	0·115	100	0·059	0·266
	1927–28	34	0·89	0·133	0·59	0·131	110	0·104	0·270
	1928–29	34	0·88	0·125	0·67	0·108	90	0·099	0·276
P.A. 289F	1926–27	38	0·97	0·098	0·62	0·109	88	0·053	0·217
Aligarh A. 19	1926–27	7	0·66	0·301	0·79	0·187	80	0·361	0·355
C.A. 9	*1924–25	28	0·89	0·163	0·65	0·161	144	0·164	0·300
	*1925–26	28	0·87	0·147	0·65	0·148	114	0·171	0·314
	1926–27	34	0·87	0·182	0·61	0·160	119	0·185	0·266
	1927–28	30	0·86	0·176	0·63	0·151	105	0·170	0·290
	1928–29	40	0·89	0·166	0·60	0·158	127	0·239	0·279
Umri Bani	1927–28	24	0·81	0·192	0·63	0·179	93	0·188	0·271
Cambodia Co. 1	†1923–24	32	0·92	0·171	0·69	0·134	91	0·154	0·234
	†1924–25	30	0·87	0·147	0·64	0·123	91	0·093	0·284
	†1925–26	32	0·93	0·156	0·63	0·114	97	0·132	0·238
	1926–27	38	0·92	0·155	0·59	0·127	91	0·124	0·309
	1927–28	34	0·93	0·164	0·60	0·138	110	0·134	0·301
	1928–29	32	0·93	0·170	0·62	0·125	126	0·179	0·291
Nandyal 14	1926–27	34	0·93	0·191	0·61	0·223	46	0·142	0·290
Hagari 25	*1923–24	24	0·90	0·210	0·70	0·165	84	0·121	0·274
	*1924–25	28	0·86	0·172	0·66	0·154	91	0·108	0·313
	*1925–26	26	0·85	0·178	0·69	0·120	94	0·102	0·308
	1926–27	26	0·76	0·177	0·65	0·110	54	0·097	0·277
	1927–28	26	0·87	0·205	0·70	0·135	76	0·112	0·309
	1928–29	30	0·90	0·188	0·65	0·132	75	0·098	0·316
Karunganni C7	1926–27	24	0·85	0·192	0·65	0·183	57	0·170	0·260
Memphis	1925–26	38	0·95	0·181	0·62	0·155	110	0·146	0·289
Mean	—	28	0·86	0·179	0·66	0·143	95	0·147	0·293

* These seven cottons are not included in Series I

† The values given in this Table for fibre-length are those obtained from the same samples as were used for the determination of clinging-power (col. 10); in the cases marked (†) there are slight differences from the corresponding values given in Appendix III, Table I, but in no case does this difference exceed 0·02 inch.

APPENDIX IV

Table I—Predictions of Highest Standard Warp Counts from Fibre-Properties for Series I Samples

Cotton	Season	Actual Highest Standard Warp Counts	Values of Highest Standard Warp Counts Predicted From									
			Length only	Weight only	Ribbon-Width only	Strength only	Convolutions only	Rigidity only	Length and Weight	Length, Strength, and Weight	Length, Weight, and Ribbon-width	All Six Properties
Dharwar 1 ...	1926–27	34	31	24	33	24	21	30	28	28	30	29
	1927–28	32	31	24	28	26	23	29	28	28	29	28
	1928–29	34	28	27	33	28	24	29	28	28	30	29
	1929–30	30	28	23	22	25	25	28	26	27	26	25
Jayawant ...	1929–30	32	33	21	21	21	23	22	28	28	27	28
Gadag 1	1923–24	36	31	29	23	27	32	24	31	30	30	31
	1924–25	20	22	32	26	29	32	28	26	26	26	27
	1925–26	30	23	33	22	30	32	28	27	27	26	27
	1926–27	38	22	29	31	27	28	27	24	24	25	25
	1927–28	38	27	30	32	26	29	27	29	29	30	30
	1928–29	26	23	31	35	26	30	28	26	26	28	29
	1929–30	32	25	30	30	27	33	27	27	27	28	29
1027 A.L.F. ...	1926–27	32	39	24	19	24	26	27	34	34	33	33
	1927–28	30	36	23	18	24	22	29	32	31	30	29
	1928–29	32	38	24	22	24	21	29	33	33	32	31
	1929–30	34	39	27	18	24	18	27	35	36	34	32
Wagad 4	1925–26	14	22	16	22	26	20	23	18	17	19	17
	1926–27	16	26	15	25	23	18	25	21	21	22	20
	1927–28	18	20	27	23	30	18	30	22	21	22	19
	1928–29	16	25	22	15	27	19	26	23	23	22	20
Wagad 8	1925–26	12	20	15	22	27	21	27	16	15	17	15
	1926–27	14	21	14	21	23	18	23	16	16	17	15
	1927–28	15	18	26	21	29	18	29	20	20	19	17
	1928–29	15	21	18	16	26	20	28	18	18	18	16
	1929–30	12	15	23	15	28	19	28	17	17	16	14
P.A. 4F	1926–27	24	19	35	23	28	27	31	25	26	24	24
	1927–28	22	20	27	23	25	27	24	22	22	22	22
	1928–29	16	16	25	25	24	27	22	19	20	19	20
	1929–30	20	22	28	24	24	28	23	24	25	24	25
P.A. 285F ...	1923–24	34	34	37	26	28	34	33	37	37	36	37
	1924–25	34	34	32	19	27	33	31	34	34	32	34
	1925–26	28	35	32	24	26	32	28	35	35	34	35
	1926–27	34	23	40	30	30	27	33	31	31	30	30
	1927–28	34	31	35	35	28	29	30	34	34	35	35
	1928–29	34	30	37	26	30	25	31	34	33	33	32
	1929–30	42	34	31	28	25	30	26	34	35	34	35
P.A. 289F ...	1926–27	38	39	41	32	30	25	34	42	42	42	41
	1927–28	40	36	34	32	28	30	31	37	37	37	37
	1928–29	38	38	37	36	26	30	31	40	40	41	42
	1929–30	42	42	33	33	26	34	31	41	41	41	43
Mollisoni	1926–27	8	8	13	15	24	21	22	7	7	7	6
	1927–28	8	13	2	3	21	29	8	6	5	4	6
	1928–29	7	9	7	16	22	28	5	5	5	6	8
	1929–30	8	9	8	10	24	25	12	6	5	5	6
Aligarh A. 19 ...	1926–27	7	6	8	13	22	23	14	3	3	3	3
	1927–28	7	10	7	9	21	22	8	6	6	5	6
	1928–29	7	11	4	18	18	21	—	5	6	6	8
	1929–30	7	8	5	14	19	22	5	3	3	3	5
Cawnpore K. 22 ...	1926–27	12	13	18	22	23	22	19	13	13	14	14
	1927–28	12	15	17	14	23	22	13	14	14	13	12
	1928–29	14	19	20	25	24	21	21	18	18	19	20
	1929–30	11	10	20	25	24	23	12	12	12	14	13

APPENDIX IV—*continued*

Table I—Predictions of Highest Standard Warp Counts from Fibre-Properties for Series I Samples

Cotton	Season	Actual Highest Standard Warp Counts	VALUES OF HIGHEST STANDARD WARP COUNTS PREDICTED FROM									
			Length only	Weight only	Ribbon-Width only	Strength only	Convolutions only	Rigidity only	Length and Weight	Length, Strength, and Weight	Length, Weight, and Ribbon-width	All Six Properties
J.N. 1	1926–27	14	18	17	22	22	21	23	16	16	16	16
	1927–28	14	14	20	22	21	22	21	15	16	15	16
	1928–29	13	16	18	21	20	24	19	16	17	16	17
	1929–30	12	15	18	22	22	24	18	15	15	15	16
C.A. 9	1926–27	34	28	27	33	25	30	25	28	29	30	31
	1927–28	30	27	28	31	26	28	26	28	28	29	29
	1928–29	40	31	30	34	25	31	22	31	31	32	33
	1929–30	34	28	29	30	24	28	18	29	30	30	31
Akola Verum ...	1928–29	23	24	26	31	23	23	28	25	26	26	26
	1929–30	21	25	25	31	24	25	24	25	25	26	26
Nagpur Verum ...	1928–29	26	26	22	32	21	22	25	24	25	26	26
	1929–30	21	22	26	29	23	25	23	23	24	24	25
Umri Bani ...	1926–27	24	22	24	26	22	21	27	22	23	23	22
	1927–28	24	22	26	31	23	26	25	23	24	24	25
	1928–29	22	24	27	31	23	25	24	25	26	26	26
	1929–30	27	22	29	29	24	25	25	25	25	24	26
Cambodia Co. 1 ...	1923–24	32	33	29	24	28	25	27	32	32	31	31
	1924–25	30	27	33	30	29	25	31	30	30	30	30
	1925–26	32	33	32	31	30	26	29	33	33	34	33
	1926–27	38	34	32	35	28	25	29	34	34	36	35
	1927–28	34	35	30	34	27	29	29	34	34	35	35
	1928–29	32	35	29	32	29	31	26	34	33	35	35
	1929–30	34	31	29	23	27	30	26	30	30	30	31
Cambodia Co. 2 ...	1927–28	33	30	34	32	29	28	28	32	33	33	33
	1928–29	26	34	33	33	31	25	31	35	34	35	34
	1929–30	28	31	29	30	29	29	23	31	30	31	32
Nandyal 14 ...	1926–27	34	35	26	33	18	18	27	32	34	34	33
	1927–28	31	30	25	26	18	20	28	28	30	28	28
	1928–29	31	33	27	28	17	20	26	31	33	31	32
	1929–30	35	33	26	28	17	22	26	31	33	31	32
Hagari 1	1928–29	24	25	23	28	27	23	27	24	24	25	24
	1929–30	27	25	26	22	28	25	29	25	25	25	24
Hagari 25 ...	1926–27	26	17	28	28	30	19	31	20	20	21	19
	1927–28	26	28	24	23	27	23	30	26	26	26	25
	1928–29	30	32	26	28	28	23	31	30	29	30	29
	1929–30	25	26	23	27	27	21	29	25	24	25	24
Karunganni C7 ...	1926–27	24	26	26	28	22	20	26	26	27	27	26
	1927–28	24	26	27	32	23	21	27	27	27	28	27
	1928–29	20	22	27	23	25	22	25	23	24	23	22
	1929–30	23	24	25	14	24	19	23	24	25	22	21
Mississippi ...	1923–24	30	41	27	28	23	34	28	37	38	37	36
Memphis	1925–26	40	37	28	32	26	29	28	34	34	35	39
Texas	1925–26	30	27	19	36	24	33	24	26	26	28	30

APPENDIX IV—*continued*

Table II—Predictions of Highest Standard Warp Counts from Fibre-Properties for Series II Samples

Cotton	Season	Actual Highest Standard Warp Counts	VALUES OF HIGHEST STANDARD WARP COUNTS PREDICTED FROM									
			Length only	Weight only	Ribbon-Width only	Strength only	Convolutions only	Rigidity only	Clinging-power only	Length and Weight	Length, Weight, Ribbon-width, and Clinging-power	All Seven Fibre Properties
Gadag 1	1923–24	36	29	29	23	28	34	25	31	29	28	29
	1924–25	20	22	32	27	29	34	29	34	26	28	28
	1925–26	30	24	33	22	31	34	28	33	29	27	28
	1926–27	38	23	28	32	28	30	28	30	25	28	28
	A1927–28	38	28	30	33	28	31	28	35	29	33	32
	*B1927–28	24	23	27	29	26	29	26	33	25	27	27
	*C1927–28	32	25	30	26	29	33	26	33	28	28	29
	1928–29	26	24	31	36	28	32	28	26	28	30	30
Wagad 4	1925–26	14	22	16	22	28	22	23	15	16	15	15
	1926–27	16	27	16	26	25	20	25	21	19	20	18
	1927–28	18	21	28	23	31	20	31	26	24	21	20
	1928–29	16	26	22	15	28	22	26	22	23	18	17
Wagad 8	1925–26	12	20	15	22	28	23	27	12	15	12	12
	1926–27	14	22	14	21	25	20	23	22	15	15	14
	1927–28	15	19	26	21	29	20	29	29	22	20	18
	1928–29	15	22	18	16	28	22	29	14	18	13	12
P.A. 285F ...	1923–24	34	35	37	27	29	36	34	32	38	35	34
	1924–25	34	34	32	20	28	35	31	31	34	30	29
	1925–26	28	37	32	24	28	34	29	28	36	32	32
	1926–27	34	24	40	30	30	29	33	32	34	32	31
	1927–28	34	31	35	36	29	30	31	31	35	36	35
	1928–29	34	30	36	27	31	27	31	30	35	32	31
P.A. 279F ...	1926–27	38	39	41	33	31	27	34	38	43	43	40
Aligarh A. 19 ...	1926–27	7	9	9	12	25	26	15	20	4	3	6
C.A. 9	*1924–25	28	31	30	29	27	36	27	27	31	31	31
	*1925–26	28	29	33	29	28	31	27	25	32	30	31
	1926–27	34	29	28	34	27	32	26	32	28	32	32
	1927–28	30	28	29	32	27	30	27	28	28	30	30
	1928–29	40	31	30	35	27	33	22	30	31	34	35
Umri Bani ...	1927–28	24	23	26	32	25	28	25	31	24	27	26
Cambodia Co. 1 ...	1923–24	32	34	29	24	29	27	28	36	32	32	31
	1924–25	30	29	33	30	30	27	31	29	32	32	30
	1925–26	32	35	32	32	30	28	29	35	34	36	35
	1926–27	38	34	32	36	29	27	29	26	34	35	34
	1927–28	34	35	30	35	28	30	29	27	34	35	34
	1928–29	32	35	29	33	29	33	26	28	33	34	35
Nandyal 14 ...	1926–27	34	35	26	34	22	20	28	28	31	33	29
Hagari 25 ...	*1923–24	24	32	23	23	26	26	30	30	27	27	24
	*1924–25	28	28	29	28	27	27	30	25	29	28	26
	*1925–26	26	27	28	24	30	28	31	26	27	26	25
	1926–27	26	28	28	29	31	21	31	30	23	24	22
	1927–28	26	29	24	23	29	25	30	26	26	24	23
	1928–29	30	32	27	29	29	25	31	25	29	29	27
Karunganni ...	1926–27	24	27	26	29	25	22	26	22	26	28	26
Memphis	1925–26	38	37	28	33	27	30	28	29	33	34	33

* These seven cottons are not included in Series I

APPENDIX V

Table I—Total and Partial Correlation Coefficients for Fibre-Properties for Series I Samples

Total Correlation Coefficients		Partial Correlation Coefficients									
		First Order		Second Order		Third Order		Fourth Order		Fifth Order	
12	·87	12·3	·7409	12·35	·7204	12·345	·7181	12·3456	·7278	12·34567	7033
		12·5	·8616								
13	—·80	13·2	—·5765	13·25	—·5578	13·245	—·4130	13·2456	—·3830	13·24567	—·3568
		13·5	—·7941								
14	—·69	14·2	—·4792	14·23	—·2578	14·235	—·2298	14·2356	—·2275	14·23567	—·2292
		14·3	—·3033	14·25	—·4619						
		14·5	—·6627	14·35	—·2446						
15	—·33	15·2	—·2356	15·23	·1600	15·234	·1070	15·2346	·1355	15·23467	·1030
		15·3	·2931								
16	·46	16·2	·3888	16·23	·2542	16·234	·2577	16·2345	·2703	16·23457	·2044
		16·3	·1866	16·25	·3488	16·235	·2721				
		16·5	·3963	16·35	·2191	16·245	·3149				
						16·345	·2148				
17	—·67	17·2	—·2380	17·23	·2218	17·234	·2113	17·2345	·1892	17·23456	·0574
		17·3	—·0625	17·25	—·1286	17·235	·1840	17·2346	·1052		
		17·5	—·6223	17·35	—·1347	17·245	—·0123	17·2356	·0499		
						17·345	—·1282	17·2456	—·1594		
								17·3456	—·2698		
23	—·68	23·1	·0541	23·15	·0100						
		23·5	—·6811								
24	—·57	24·1	·0849	24·15	·0816	24·135	·0843				
		24·3	—·1795	24·35	—·1198						
		24·5	—·5401								
25	—·25	25·1	·0797								
		25·3	·2555								
26	·32	26 1	—·1832	26·15	—·1712	26·135	—·1708	26·1345	—·1721		
		26·3	·0214	26 35	·0422	26·345	·0371				
		26·5	·2616								
27	—·67	27 1	—·2380	27 15	— 3262	27·135	—·3716	27·1345	—·3739	27·13456	—·3383
		27·3	—·2773	27·35	— 3522	27·345	—·3501	27·3456	—·4196		
		27·5	—·6658								
34	·70	34·1	·3408	34·12	·3382	34·125	·3846				
		34·2	·5188	34·15	3837						
		34·5	·7011	34 25	5408						
35	·59	35·1	·5754	35·12	·5740						
		35·2	·5916								
36	—·45	36·1	—·1539	36·12	—·1467	36 125	—·0469	36·1245	—·0523		
		36·2	—·3346	36·15	—·0478	36·245	—·1754				
		36·5	—·3414	36·25	—·2312						
37	·81	37·1	·6152	37·12	·6477	37·125	·4860	37·1245	·4448	37 12456	·5170
		37·2	·6512	37·15	·4560	37·245	·4104	37·2456	·5328		
		37·5	·7112	37·25	·4720						
45	·26	45·1	·0473	45 12	·0409	45 123	—·1988				
		45·2	·1478	45·23	—·2307						
		45·3	—·2654								
46	—·33	46·1	—·0196	46·12	—·0042	46·123	—·0488	46 1235	·0234		
		46·2	—·1897	46·15	—·0105	46·125	·0036				
		46·3	—·0235	46·23	—·0200	46·135	·0085				
		46·5	—·2698	46·25	—·1582	46·235	—·0406				
				46·35	—·0453						
47	·56	47 1	·1819	47·12	·2088	47·123	—·0144	47·1235	·0449	47·12356	0383
		47·2	·2920	47·15	·1836	47·125	·2231	47·2356	·0261		
		47·3	—·0167	47·23	—·0703	47·135	·0105				
		47·5	·5202	47·25	·2558	47·235	·0008				
				47·35	·0430						
56	—·32	56·1	—·2006	56·12	—·1899	56·123	—·1305	56·1234	—·1234		
		56·2	—·2616	56·23	—·0839	56·234	—·0910				
		56·3	—·0756								
57	·58	57·1	·5122	57·12	·5486	57·123	·2833	57·1234	·2862	57·12346	·3828
		57·2	·5738	57·23	·3084	57·234	·3011	57·2346	·3920		
		57·3	·2156								
67	—·13	67·1	·2704	67·12	·2374	67·123	·4410	67·1234	·4422	67 12345	·5025
		67·2	·1200	67·15	·4434	67·125	·4163	67·1235	·5030		
		67·3	·4477	67·23	·4723	67·135	·5234	67·1245	·4262		
		67·5	·0721	67·25	·3421	67·234	·4722	67·1345	·5233		
				67 35	·4765	67·235	·5260	67·2345	·5265		
						67·245	·4009				
						67·345	·4794				

APPENDIX V—*continued*

Table II—Total and Partial Correlation Coefficients for Fibre-Properties for Series II Samples

Total Correlation Coefficients		Partial Correlation Coefficients											
		First Order		Second Order		Third Order		Fourth Order		Fifth Order		Sixth Order	
12	·72	12·3	·5356	12·34	·4856	12·345	·4585	12·3456	·4698	12·34567	·5087	12·345678	·5156
13	—·78	13·2	—·6482	13·24	—·5571	13·245	—·4804	13 2456	—·3503	13 24567	—·4059	13·245678	—·2271
14	—·71	14·2	—·5825	14·23	—·4629	14·235	—·4101	14·2356	—·4467	14·23567	—·4171	14·235678	—·4368
		14·3	—·5162										
15	—·23	15 2	— 2492	15 23	·2500	15·234	0854	15 2346	·0348	15 23467	—·0328	15·234678	—·0707
		15·3	3809	15 24	—·3317								
				15·34	·1986								
16	·59	16·2	·4930	16·23	·2738	16·234	·3198	16·2345	·3111	16·23457	·1316	16·234578	·1603
		16 3	·2700	16·24	·4889	16·235	·2482						
				16·34	·3159	16·245	·4561						
						16·345	·2907						
17	—·40	17·2	—·1227	17 23	·4236	17·234	·3627	17 2345	3555	17 23456	·2224	17·234568	·1600
		17·3	3052	17·24	—·1094	17·235	3659	17·2346	·2231				
				17 34	·2366	17·245	·1269	17 2356	·2808				
						17 345	·1934	17·2456	—·0410				
								17·3456	·0345				
18	— 67	18·2	— 5838	18·23	—·2634	18·234	— 2599	18 2345	—·2466	18 23456	— 2436	18 2345[illegible]	[illegible]
		18·3	—·2205	18·24	—·5174	18·235	—·2044	18 2346	—·2434	18 23457	—·1655		
				18·34	—·2163	18·245	—·4724	18 2356	—·1976	18·23467	—·1786		
						18·345	—·1710	18 2456	—·3900	18·23567	—·1259		
								18·3456	— 1650	18·24567	—·3886		
										18 34567	—·1628		
23	—·57	23 1	- 5162										
24	—·50	24·1	·0229	24 13	·0236								
		24·3	— 2593										
25	—·08	25·1	·1268	25·13	·1747	25·134	1915						
		25·3	·3403	25 34	·2605								
26	·38	26 1	—·0800	26 13	—·0871	26·134	— 0925	26·1345	—·1197				
		26·3	·0738	26·34	·0766	26·345	·0315						
27	—·45	27·1	—·2548	27·13	—·3220	27·134	—·3212	27·1345	— 3850	27 13456	- 3850		
		27·3	—·0953	27·34	—·1579	27·345	— 2470	27 3456	— 3232				
28	—·42	28·1	·1212	28·13	·1473	28·134	·1489	28·1345	·2061	28 13456	2082	28 134567	·0966
		28·3	0033	28·34	·0220	28·345	·1020	28·3456	1035	28·34567	— 0008		
34	·57	34·1	·0368	34·12	0372								
		34·2	·4005										
35	·55	35·1	·6087	35 12	6160	35·124	·6419						
		35·2	6158	35 24	·6879								
36	— 58	36·1	— 2371	36 12	— 2394	36·124	—·2486	36 1245	— 2816				
		36 2	—·4782	36 24	—·4526	36·245	—·4393						
37	·69	37 1	6592	37·12	·6767	37·124	·6778	37 1245	·4669	37·12456	·6204		
		37·2	5907	37·24	·6203	37·245	·3448	37·2456	5948				
38	·74	38 1	·4680	38·12	·4740	38·124	·4758	38·1245	·5279	38·12456	·5177	38·124567	·5537
		38·2	·6714	38·24	·6263	38·245	·6351	38·2456	5833	38·24567	·6241		
45	·01	45·1	—·2238	45·12	-- 2287	45·123	—·3197						
		45·2	— 0347	45·13	—·3106								
		45·3	—·4423	45 23	—·3897								
46	—·33	46·1	·1563	46·12	·1587	46·123	·1728	46 1235	·2105				
		46·2	- 1748	46·13	·1700	46·235	·0845						
		46·3	0009	46 23	·0208								
47	·27	47·1	—·0217	47 12	—·0164	47·123	—·0565	47·1235	·0522	47·12356	—·0770		
		47·2	·0582	47·13	—·0611	47·235	— 1059	47·2356	—·1919				
		47·3	—·2073	47 23	— 2413								
48	·46	48·1	—·0300	48 12	—·0331	48·123	—·0576	48 1235	—·1496	48·12356	—·1524	48·123567	—·1780
		48·2	·3181	48 13	·0534	48·235	—·0497	48·2356	—·0454	48·23567	—·1081		
		48·3	·0691	48·23	0725								

APPENDIX V—*continued*

Table II—Total and Partial Correlation Coefficients for Fibre-Properties for Series II Samples

Total Correlation Coefficients		Partial Correlation Coefficients											
		First Order		Second Order		Third Order		Fourth Order		Fifth Order		Sixth Order	
56	– 21	56·1	—·0946	56·12	—·0855	56·123	·0810	56·1234	·1461				
		56·2	—·1948	56·13	·0645	56·124	—·0512						
		56·3	·1603	56·23	·1441	56·134	·1252						
				56·24	—·2042	55·234	·1653						
				56·34	·1792								
57	58	57·1	·5473	57·12	·6043	57·123	·3231	57·1234	·3224	57·12346	·2936		
		57·2	·6110	57·13	·2447	57·124	·6170	57 2346	·2930				
		57·3	·3317	57·23	·3887	57·134	·2380						
				57·24	·6145	57·234	·3297						
				57·34	·2736								
58	·25	58·1	·1327	58·12	·1191	58·123	—·2493	58 1234	—·2830	58·12346	—·2842	58·123467	– 2079
		58·2	·2393	58·13	—·2169	58·124	·1147	58·2346	—·2835	58 23467	—·1984		
		58·3	—·2796	58·23	—·2983	58·134	—·2461						
				58·24	·2642	58·234	—·2941						
				58·34	—·2784								
67	– 06	67·1	·2379	67·12	·2257	67·123	·5424	67·1234	·5615	67·12345	5494		
		67·3	·5772	67·13	·5396	67·124	·2312	67·1235	·5474				
				67·23	·5883	67·134	·5593	67·1245	·3344				
				67·24	·1471	67·234	·6113	67·1345	·5496				
				67·34	·5903	67·235	·5838	67·2345	·5980				
						67·245	·3530						
						67·345	·5722						
		68·1	—·1414	68·12	—·1331	68·123	– 0230	68·1234	—·0132	68·12345	·0297	68·123457	1757
		68·2	—·3817	68·13	—·0355	68·124	—·1295	68·1235	—·0029	68·23457	·1496		
		68·3	—·0927	68·23	—·0933	68·134	– 0268	68·1245	—·1246				
				68·24	—·3493	68·234	—·0951	68·1345	·0042				
				68·34	—·0930	68 235	—·0533	68 2345	—·0493				
						68·245	—·3129						
						68·345	– 0456						
	34	78·1	·1058	78·12	·1424	78·123	–·2751	78·1234	– 2793	78·12345	—·2072	78·123456	—·2676
		78·2	·1863	78·13	—·3049	78·124	1420	78 1235	—·2123	78·12346	– 3286		
		78·3	—·3504	78·23	—·3518	78·134	—·3093	78·1245	·0911	78·12356	—·2518		
				78·24	·1773	78·234	– 3453	78·1345	—·2663	78 12456	·1420		
				78·34	– 3444	78·235	– 2682	78·2345	– 2754	78 13456	–·3215		
						78·245	0196	78·2346	—·3646	78 23456	—·3072		
						78·345	—·2904	78·2356	—·2924				
								78 2456	·1464				
								78·3456	– 3226				

Note on Tables I and II of Appendix V

In each column of these Tables, the figures on the right-hand side show the value of the correlation coefficient for the fibre-properties indicated by the figures on the same line on the left-hand side, *e g*. Table II, col 1, line 1: ·72 is the total correlation coefficient for properties 1 and 2, the fibre-properties indicated by the numerals 1 to 8 being—

1 = highest standard warp count;
2 = fibre-length;
3 = fibre-weight per inch;
4 = fibre-width;
5 = fibre-strength;
6 = fibre-convolutions per inch;
7 = fibre-rigidity;
8 = fibre-clinging power.

Note by A. J. T.

The data on which this paper is based were obtained while I was Director of the Technological Laboratory; the delay in the completion of the paper has been occasioned by the pressure of my other work since I entered the service of the British Cotton Industry Research Association.

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2—FIBRE-LENGTH IRREGULARITY IN COTTON

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SUMMARY

The importance of regularity of staple, besides its length, has long been recognised by the spinners and other practical men engaged in the textile industry. Hitherto, with one recent exception, no objective method has been put forward for determining the staple irregularity of a cotton from experimental data. The object of this paper is to suggest such a method, to apply it to a large number of cottons tested at the Technological Laboratory, and to examine the results obtained with reference to their chief fibre-properties and spinning performance. It is pointed out that the most rational way of calculating the fibre-length irregularily of a cotton would be to base it upon some property indicative of its length, and reasons are advanced for selecting for this purpose the modal in preference to the mean fibre-length. Accordingly the fibre-length irregularity is defined as the percentage ratio by weight of all the fibres in a representative sample which measure less than three-fourths of the modal length.

Values of fibre-length irregularity, calculated according to the method described above, are given for 63 Standard Indian Cottons and 30 agricultural samples. The results for the Standard Cottons and the simple correlation coefficient between mean fibre-length and irregularity show that the comparatively long cottons have a tendency to be somewhat more irregular than the short ones. This, however, is *not* always the case, and the anomaly completely disappears when we consider the results and the correlation coefficient for the agricultural samples, which cover a much wider range of fibre-properties than the Standard Cottons.

Values of simple and multiple correlation coefficients between the highest standard warp counts, the mean fibre-length, the fibre-weight per inch, and fibre-length irregularity are given for both series of samples, and their inter-relationships are discussed. It is found that the inclusion of fibre-length irregularity does not raise the multiple correlation coefficient between the highest standard warp counts and mean fibre-length and fibre-weight per inch. It is pointed out that this correlation is already so high (0·906 for the Standard Cottons and 0·937 for the agricultural samples) that unless a fibre-property be compatible in importance with length and weight, its effect in modifying the correlation coefficient is likely to be small.

The present method is compared with an earlier one, described by Clegg in this *Journal*, for calculating a similar property called "percentage short hairs."

I—INTRODUCTION

The spinning capacity of a cotton depends mainly upon three sets of factors, viz. (*a*) the physical and chemical properties of its fibres; (*b*) the mechanical treatment to which it is subjected in the cleaning and carding processes; and (*c*) the appropriateness of settings, speeds, twists, and drafts in the fly-frames and the ring-frame. Whereas the first set of factors is characteristic of the cotton itself, the second and the third owe their importance to the interaction of fibres with machinery which, by bringing about the necessary parallelisation, alignment, and cohesion in them, gives the requisite evenness, lustre, and strength to its yarn.

Among the first set of factors, it has been recognised for some time past that the staple length of a cotton plays the most important part. Recent researches into the relative importance of the various fibre-properties of a cotton with reference to its spinning capacity have confirmed this view by showing that the correlation coefficient between the highest standard warp counts for which a cotton is adjudged suitable and the mean fibre-length is higher than that between the highest standard warp counts and any other fibre property. It is, therefore, hardly surprising to find that long before laboratory methods for the determination of mean fibre-length were developed the pressing need of the industry had organised a class of experts, known as graders, who, by virtue of long training and experience, were able to estimate it fairly accurately in the case of commercial types familiar to them.

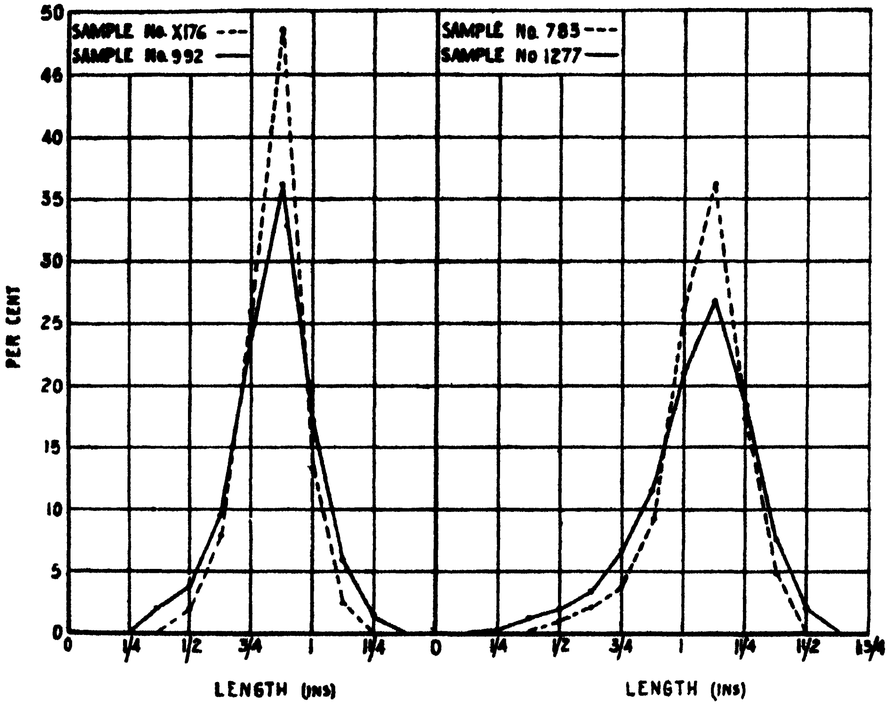

FIG. 1

The mean fibre-length of a cotton, as the name signifies, represents very nearly the arithmetic mean of the lengths of all the fibres present in a small representative sample. These fibres, as is well known, when placed side by side so that at one end they all start from the same straight line, form a gradation in which the fibres near one end are longer, while those near the other are shorter, than the middle ones. An idea of the extent of variation in fibre-length in one and the same sample may be formed from Fig. 1, which shows the sorter diagrams for four cottons. Taking the extreme case of Sample No. 1277, it will be seen that, with a mean length of 1·06 in., fibres near one end are over 1¼ in. long while those near the other are hardly ½ in. long. This *dispersion* of fibre-length over a fairly wide range is not confined to any particular type or growth, but is common to all cottons, though the degree of dispersion is different for different cottons. This would naturally be expected in the case of a long staple and a short staple cotton, but frequently two samples having very nearly the same mean length differ appreciably in respect of degree of dispersion of their fibre-length. On referring again to Fig. 1, it will be seen that, although the mean length is practically the same for the two members of each pair, their sorter diagrams do not coincide, showing that the percentages of fibres of different length-grades are different for each pair, the maximum difference in this case being as high as 14 per cent.

For obvious reasons the degree of dispersion of fibre-length or the relative percentages of the long and the short fibres in a given cotton form an important consideration in the spinner's estimate of a cotton. Between two samples having nearly the same mean length, he will undoubtedly choose the one in which the fibres are more regularly distributed in length. Accordingly, it has become an established practice for the grader to include "staple regularity" among the noteworthy characteristics of a cotton and to express his opinion on it in such terms as "good," "fair," "irregular," "poor," etc. This method of estimating the fibre-length irregularity of a cotton is qualitative, subject to personal errors of judgment and incapable of revealing small differences in the staple irregularity of two cottons. Hence the need for an objective method capable of giving results which are more precise than a grader's estimate and which can be correlated with the other properties of cotton. It is necessary as a preliminary step to decide whether in this method we should take into account both the long and the short fibres or only the one or the other. In order to do so we should carefully examine the part played by each class of fibres in the processing of a cotton.

The long fibres may prove a source of trouble in two ways. In the first place, being generally more fragile, they may be broken into two or more fragments by the fast and heavy beaters in the porcupine, crighton, or the scutcher, thereby increasing the percentage of the short fibres. Secondly, as the roller settings in the frames must necessarily be made with reference to the average length of the cotton, the long fibres may be snapped in pieces on being caught simultaneously between the nips of two lines of rollers. However, since the long fibres do not constitute more than 10% of the total in any cotton, the actual number of such fibres as are likely to be damaged in either of the two ways mentioned above will be quite small. Moreover, these possible defects are offset, to some extent, by the additional strength which the presence of undamaged long fibres gives to the yarn. On the whole, therefore, until it is definitely established that the yarn loses much more in strength than it gains due to the presence of long fibres, these cannot be regarded as responsible for lowering the spinning capacity of a cotton by an appreciable amount.

The position, however, is entirely different with the short fibres which, without possessing a single redeeming feature, prove a source of constant trouble. Their harmful effects are first noticeable at an early stage in the blow-room where they form a thin layer on the hopper exhaust cages and thus cause the scutcher lap to develop the well-known defect of "licking." Later, in the card-room, they constitute the bulk of the flat strip waste, thereby raising the waste losses of a cotton. Much more harmful than these is their behaviour in the fly-frames and the ring-frame. As the rollers are normally set with reference to the average length of a cotton, the settings are too wide for the very short fibres present in it. Accordingly, even if it is for the merest fraction of a second, they become what are commonly called "floating fibres," i.e. they are not held by the rollers at either end. In this state they are acted upon by the tangential forces due to the clinging action of the adjacent fibres and are thus able to disturb their orderly alignment of the latter.[1] This produces unevenness in the structure of the yarn which is mainly responsible for irregularity and deficiency in yarn strength and for abnormal breakages in the winding frame and the loom. Furthermore, their free ends, by sticking out in all directions, as a result of accumulation of electric charge, sometimes give the yarn a fuzzy appearance.

It will be clear from the foregoing discussion that the spinning capacity of a cotton is more adversely affected by the short than by the long fibres. Accordingly, we have decided to take into account only the former in developing a method for the determination of fibre-length irregularity in a cotton.

It may be asked at this stage whether the coefficient of variation of the frequency distribution of a cotton would not serve the required purpose. It is true that this statistic could be employed as a measure of the degree of dispersion of fibre-length, but its use, or the use of any of its associated statistical constants, is open to two objections. Firstly, in calculating it, we must use the relative percentages of the long as well as of the short fibres. But we have just seen that several reasons point to the desirability of excluding the long fibres and restricting ourselves to the short fibres in deriving a formula for the staple irregularity of a cotton. Secondly, the coefficient of variation is essentially a mathematical abstraction and it is possible that its full significance may not be grasped by the practical men engaged in the textile industry.

II—METHOD

Any method of determining the fibre-length irregularity of a cotton must employ one or the other of the following two alternatives. It must either single out, from a representative sample, all those fibres which are shorter than a certain specified length and express the fibre-length irregularity by the percentage ratio of the weight of such fibres to the weight of the sample. This method is open to the very serious objection that the proportion of fibres measuring less than the specified length will be very much higher in the case of a short staple cotton than in that of a long staple one. This will be seen from Table I which shows the fibre-length distribution for three Indian cottons representing a long, a medium, and a short staple type.

Table I

Mean Group Lengths in eighths of an inch	289F (1929–30)	Umri Bani (1929–30)	A.19 (1930–31)
2	0	0	1·8
3	1·6	2·2	4·4
4	2·3	4·8	13·7
5	4·6	11·0	42·1
6	7·6	25·5	28·1
7	13·8	35·5	8·5
8	23·7	16·7	1·4
9	25·4	4·3	—
10	14·2	—	—
11	5·5	—	—
12	1·3	—	—
Mean length (inches)	1·01	0·82	0·65

It will be seen that if we select 0·56 in. as the minimum specified length then the percentage of short fibres is only 3·9 in P.A.289F., 7·0 in Umri Bani, and as high as 19·9 in A.19. According to this method, therefore, we shall inevitably obtain abnormally high values of fibre-length irregularity for the short staple cottons and very low values for the long staple growths. This conclusion is not only contrary to everyday experience but makes it impossible to compare different classes of cotton as regards their staple irregularity. This alternative is, therefore, ruled out.

The second alternative is to select those fibres in a representative sample which are shorter than a certain fraction of some quantity representing the staple length of the cotton and to express the irregularity as the percentage ratio of the weight of such fibres to the weight of the sample. The choice of the fraction, referred to above, must necessarily be arbitrary. This is undoubtedly a weak spot in this method but it is unavoidable until we possess much more information than is at present available as regards the contribution of each length-grade to yarn strength. In the meantime, this alternative appears to be capable of giving the best results.

Having adopted the second alternative we have to decide whether we should adopt the mean fibre-length or the modal length as the physical property representing the staple length of a cotton. We have the parallel case of strength regularity of a yarn in which the arithmetic mean of the observations is employed in the calculations. This might at first sight incline us to adopt the mean fibre-length as the basis for the fibre-length irregularity. It should, however, be remembered that yarn strength results (corrected for actual counts in the case of the single thread tests) always give a normal distribution in which the mean and the mode coincide. If, therefore, instead of the mean, we took the mode the result would be just the same. On the other hand, the fibre-length distribution has generally a negative skewness, the skewness increasing with the staple length of the cotton, so that the modal length is usually somewhat greater than the mean fibre-length. As the two statistics would yield different values of fibre-length irregularity, especially for the long staple cottons, it is important to decide which one should be employed.

For this purpose the relative importance of the two statistics with reference to the spinning capacity of a cotton should be the first consideration. In Table II are given the highest standard warp counts[2] for which 63 Standard Indian Cottons are adjudged suitable together with the values of their mean fibre-length, modal length, fibre-weight per inch and fibre-length irregularity, while Table III shows the simple correlation coefficients between the mean and the mode, the mean and the highest standard warp counts, and mode and the highest standard warp counts.

It will be seen that the correlation coefficient between the highest standard warp counts and the modal length has exactly the same value as that between the former and the mean fibre-length. This is to be expected in view of high correlation coefficient between the mean fibre-length and the modal length, which is found to be almost equal to unity. It follows, therefore, that so far as its relationship with the spinning capacity of cotton is concerned the modal length is just as important as the mean fibre-length. Not only can its use be justified on this ground, but, as a basis for the calculation of fibre-length irregularity it possesses at least two advantages over the mean fibre-length.

Table II

Mean Length, Modal Length, Fibre-weight, Length Irregularity, and Highest Standard Warp Counts of 63 Samples

Sample No.	Cotton	Season	Highest Standard Warp Counts	Mean (in.)	Mode (in.)	Fibre Weight per in. (10^{-6} oz.)	K.
497	Dharwar 1	28–29	34	0·87	0·93	0·164	16·2
733	,,	29–30	30	0·89	0·93	0·190	14·3
1055	,,	30–31	30	0·86	0·90	0·164	13·6
734	Jayawant	29–30	32	0·91	0·97	0·190	16·1
1056	,,	30–31	30	0·87	0·90	0·196	14·0
1304	,,	31–32	33	0·89	0·93	0·177	16·3
719	Gadag 1	29–30	32	0·85	0·90	0·148	13·0
1015	,,	30–31	35	0·86	0·91	0·153	15·6
1305	,,	31–32	29	0·79	0·83	0·154	15·5
716	Surat 1027 A.L.F.	29–30	34	0·97	1·02	0·180	12·9
1018	,,	30–31	29	0·93	1·00	0·201	16·8
1313	,,	31–32	30	0·90	0·95	0·175	19·7
698	Wagad 8	29–30	12	0·77	0·77	0·195	10·1
1001	,,	30–31	12	0·76	0·77	0·257	11·3
1300	,,	31–32	16	0·79	0·84	0·225	17·6
659	P.A. 4 F.	29–30	20	0·81	0·86	0·155	14·9
995	,,	30–31	22	0·78	0·78	0·198	11·5
1243	,,	31–32	20	0·71	0·72	0·161	10·7
660	P.A. 289 F.	29–30	42	1·02	1·09	0·142	16·9
994	,,	30–31	44	0·96	1·04	0·142	20·1
1239	,,	31–32	39	0·89	0·95	0·122	17·3
643	Mollisoni	29–30	8	0·70	0·72	0·272	9·8
996	,,	30–31	8	0·68	0·69	0·287	11·9
1240	,,	31–32	8	0·69	0·69	0·242	11·0
693	A. 19	29–30	7	0·70	0·72	0·277	11·5
948	,,	30–31	7	0·65	0·65	0·301	11·8
1286	,,	31–32	6	0·67	0·65	0·314	11·1
648	K. 22	29–30	11	0·70	0·72	0·210	11·9
946	,,	30–31	12	0·77	0·77	0·196	10·8
1227	,,	31–32	12	0·73	0·75	0·217	11·2
456	Bundelkhand Jn. 1	28–29	13	0·78	0·78	0·212	10·8
690	,,	29–30	12	0·76	0·77	0·229	11·0
979	,,	30–31	12	0·76	0·78	0·218	12·2
689	C.A. 9	29–30	34	0·86	0·90	0·165	13·8
980	,,	30–31	37	0·86	0·90	0·154	13·0
1265	,,	31–32	36	0·84	0·89	0·157	14·1
628	Verum 262 (Nagpur)	29–30	21	0·82	0·86	0·166	12·6
962	,,	30–31	26	0·83	0·87	0·186	12·6
1242	,,	31–32	25	0·82	0·87	0·176	15·2
618	Verum 262 (Akola)	29–30	21	0·85	0·89	0·176	13·1
908	,,	30–31	18	0·80	0·82	0·170	13·1
1241	,,	31–32	21	0·77	0·80	0·174	14·1
635	Umri Bani	29–30	27	0·82	0·87	0·152	14·8
981	,,	30–31	28	0·79	0·82	0·175	14·0
1228	,,	31–32	27	0·79	0·82	0·172	13·7
496	Cambodia Co. 1	28–29	32	0·93	1·00	0·153	16·1
735	,,	29–30	34	0·89	0·93	0·146	13·3
1049	,,	30–31	29	0·87	0·91	0·156	12·9
706	Cambodia Co. 2	29–30	28	0·90	0·97	0·136	17·0
1057	,,	30–31	29	0·92	1·02	0·133	19·7
1356	,,	31–32	27	0·90	0·98	0·145	18·6
726	Nandyal 14	29–30	35	0·92	0·99	0·169	15·9
1044	,,	30–31	35	0·85	0·91	0·167	14·7
1334	,,	31–32	30	0·85	0·91	0·187	16·4
736	Hagari 1	29–30	27	0·84	0·88	0·175	13·8
1031	,,	30–31	36	0·91	0·94	0·166	10·1
1311	,,	31–32	30	0·85	0·90	0·172	14·8
737	Hagari 25	29–30	25	0·86	0·90	0·178	13·2
1032	,,	30–31	36	0·90	0·93	0·195	11·5
1312	,,	31–32	31	0·89	0·93	0·185	14·8
717	Karunganni C7	29–30	23	0·84	0·90	0·181	16·4
1045	,,	30–31	26	0·82	0·87	0·161	16·6
1320	,,	31–32	21	0·81	0·85	0·181	17·1

In the first place, majority of cottons show greater symmetry in fibre-length distribution about their mode than about the mean. The short staple cottons, having very nearly a normal distribution, would naturally conform to this rule, but it also holds equally well for long staple cottons in which the mean and the mode do not generally coincide. Secondly the modal length, at least to a practical man, is a more tangible physical reality than the mean fibre-length. This will be clear if we visualise the procedure followed by a grader in "pulling" a cotton for its staple length. Since the fibres possessing the modal length (or nearly so) form the majority in a sample, the mental impression produced by them is much stronger than by fibres of any other length-grade. It is on this account we generally find that the grader's estimate of the staple length of a cotton agrees better with its modal length than its mean fibre-length.

In view of the reasons given above, it has been decided to employ the modal length of a cotton as the basis for the calculation of its fibre-length irregularity. Once this point is settled, the rest follows in a straightforward manner. The fibre-length irregularity, denoted hereafter by K, is defined as the percentage ratio of the weight of all those fibres in a representative sample, whose individual lengths are less than three-fourths of the modal length, to the weight of the sample. Column 6 of Table II, referred to above, shows the values of K calculated according to this method for 63 Standard Indian Cottons.

III—DISCUSSION

We shall first discuss the results obtained by the application of this method and their bearing upon the physical properties and the spinning capacity of cotton, and will then compare this method with an earlier one described by Miss Clegg* in the *Journal of the Textile Institute.*[3]

An examination of the values of K given in column 6 of Table II may incline one to suspect that the proposed method suffers from a bias against the long staple cottons in the sense that these, as a rule, give higher values for irregularity percentage than the short staple cottons. This suspicion is not without some justification but the bias is neither strong nor shared by all long staple cottons. For example, K for Surat 1027 A.L.F. and Akola Verum 262 (both 1929-30 season) have practically the same value, viz. 12·9 and 13·1 respectively, but the latter cotton is some 12% shorter than the former. To illustrate this point further, Table IV has been constructed which gives the highest standard warp counts, the mean fibre-length, the fibre-weight per inch, the modal length and the fibre-length irregularity for 30 agricultural samples, which represent a much wider range of fibre-properties than the Standard Indian Cottons and which have been tested at the Technological Laboratory during the past three seasons.

Table III

Correlation Coefficient between	Value	Probable error
Mean fibre-length and modal length	0·989	0·002
Mean fibre-length and highest standard warp counts	0·88	0·02
Modal length and highest standard warp counts ...	0·88	0·02

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* See page T58.

Table IV

Length, Weight, Length Irregularity, and Highest Standard Warp Counts (30 Samples)

Sample No.	Cotton	Season	Highest Standard Warp Counts	Fibre Length (in.)	Modal Length (in.)	Fibre Weight per in. (10^{-6} oz.)	Fibre Length irregularity (%)
934	Banilla (Gargaon) ...	30–31	14	0·64	0·65	0·195	14·9
913	,, (Bharwas) ...	30–31	13	0·67	0·70	0·184	16·7
992	C 3	30–31	11	0·84	0·87	0·224	12·8
1035	1 A Long Boll ...	30–31	23	0·89	0·91	0·206	7·6
1091	1027—W8 11–4 ...	30–31	28	0·97	1·01	0·197	13·3
851	1 X C 99	29–30	18	1·03	1·10	0·228	14·6
1277	Ashmouni	31–32	60	1·06	1·14	0·166	17·0
783	Acala Ardmore ...	29–30	40	1·07	1·12	0·150	8·9
781	Ashmouni	29–30	60	1·17	1·28	0·146	15·4
1276	Boss III	31–32	80	1·23	1·43	0·116	22·1
782	,, ...	29–30	80	1·34	1·39	0·126	9·4
910	Sea Island (Andamans) ...	29–30	120	1·46	1·59	0·084	17·6
1623	Hartsville	32–33	50	1·20	1·24	0·119	16·1
1235	C 402 (Madhoganj) ...	31–32	15	0·82	0·86	0·204	13·9
1607	4F–98	32–33	36	0·84	0·87	0·148	14·3
1610	W. N. 27	32–33	6	0·63	0·63	0·299	13·2
1605	285 F–21	32–33	36	1·02	1·19	0·102	25·0
1608	4 F–18	32–33	28	0·75	0·78	0·137	14·6
1606	285 F–2	32–33	45	0·91	0·99	0·125	20·3
1534	Roseum	31–32	8	0·73	0·73	0·250	8·4
1512	Jamkhandi	31–32	16	0·80	0·86	0·195	15·7
1258	N. T. 10/30	31–32	8	0·69	0·69	0·265	10·3
1529	Strain 2622	31–32	28	0·87	0·92	0·170	15·8
1442	Upland	31–32	21	0·76	0·77	0·154	12·2
1447	Goghari E5	31–32	8	0·71	0·73	0·189	8·5
1436	Strain 23	31–32	35	0·87	0·90	0·169	10·9
1650	K. T. 23	32–33	41	1·01	1·08	0·125	13·0
1571	Egyptian	31–32	90	1·39	1·55	0·098	18·5
1522	S. G. 23/8	31–32	65	1·09	1·19	0·103	15·9
1519	B. P. 6/30	31–32	46	0·97	1·04	0·122	15·3

This table can furnish us with numerous examples to show that fibre-length irregularity may assume high or low values for the long as well as the short staple cottons and that the former are not necessarily more irregular in staple than the latter. For instance, we find that the three samples, Nos. 934, 1607, and 851 have practically the same value (c. 14·5) for fibre-length irregularity although their modal lengths are 0·65, 0·87, and 1·10 in. respectively. Similarly, K is nearly twice as high for sample No. 913 as for sample No. 782, although the modal length for the former cotton is only half that of the latter. Again, the two samples Nos. 1605 and 1522 have exactly the same modal length, but the former is over 50% more irregular in staple than the latter. The fibre-length irregularity of the longest cotton in this series, Sea Island (Andamans), is equalled, or even exceeded, by others possessing a much smaller staple length. It would be easy to give more examples either from this table or from similar data available at the Technological Laboratory, but the best way to discover any possible relationship between irregularity and staple length would be to work out the correlation coefficient between these two fibre-properties. This has been done in Table V, which also contains the values of the various simple and multiple correlation coefficients, together with the probable errors of the former, between highest standard warp counts and mean fibre-length, fibre-weight per in. and fibre-length irregularity for the 63 Standard Indian Cottons and the 30 agricultural samples mentioned above. In calculating these coefficients the mean fibre-length has been used instead of the modal length but, on account of the very close inter-relationship between the two, the results would not have differed materially if the latter had been employed.

Table V

Coefficients of Correlation. Simple and Multiple

	63 Standards		30 Samples	
	Correlation Coefficient	Probable Error	Correlation Coefficient	Probable Error
r_{12}	+0·88	0·019	+0·92	0·019
r_{13}	−0·79	0·031	−0·78	0·047
r_{14}	+0·58	0·056	+0·43	0·100
r_{23}	−0·73	0·039	−0·71	0·061
r_{24}	+0·63	0·051	+0·35	0·107
r_{34}	−0·55	0·059	−0·54	0·086
$R_{1\cdot 23}$	0·906	—	0·937	—
$R_{1\cdot 24}$	0·881	—	0·927	—
$R_{1\cdot 234}$	0·906	—	0·938	—

1—Highest standard warp counts
2—Mean fibre-length
3—Fibre-weight per inch
4—Fibre-length irregularity

We shall first discuss the results obtained for the Standard Indian Cottons. It will be seen that the correlation coefficients between irregularity and length and irregularity and highest standard warp counts are positive, while that between irregularity and fibre-weight per inch is negative, that all the three coefficients are moderately high and that the least among them—between irregularity and fibre-weight per inch—is more than nine times its probable error. If we apply Fisher's[4] test, we find that for 60 samples and $p=0\cdot 01$, the correlation coefficient should exceed 0·325 in order to be significant. We conclude, therefore, that for these cottons length is positively and significantly correlated to irregularity, i.e. the comparatively long Standard Indian Cottons have a tendency to be more irregular in staple than the short cottons. We will soon see that this conclusion is not general, as it breaks down in the case of the 30 agricultural samples which represent a wider range of staple length. We further notice that length irregularity is positively and significantly correlated to the spinning capacity of these cottons. This result, which signifies that irregular cottons are inclined to give a better performance, is unexpected, but becomes intelligible in the light of the high and positive correlation (0·88) between length and highest standard warp counts. As the long cottons have a tendency, on the one hand, to be irregular and, on the other, to give a better performance, we understand why the coefficient between irregularity and highest standard warp counts should be positive. That, in the case of these cottons, fibre-length irregularity has very little, if any, effect on their spinning performance is shown by the trend of values of the multiple correlation coefficients. We find, on comparing these with the simple coefficients, that the inclusion of fibre-length irregularity, as a contributory factor, fails to take us beyond the stage attained by confining ourselves to fibre-length and fibre-weight per inch only.

Turning now to the 30 agricultural samples of Table V, the position becomes much clearer and the anomalies noted above disappear. We notice that the simple correlation coefficients between irregularity and length of staple and between irregularity and highest standard warp counts, though still positive, are about four times their probable errors and consequently insignificant. If we apply Fisher's[5] test, the same result follows since, for 30 samples and p=0·01, the correlation coefficient must be at least 0·449 in order to be significant. We thus find that if we take a sufficiently wide range of staple length, the probability that a long cotton will show greater staple irregularity is quite small, and that the irregular cottons will not, as a rule, give a better performance. In one respect, however, the behaviour of these 30 samples is similar to that of the Standard Indian Cottons. On comparing the simple with the multiple coefficients, we do not find any improvement in the values of the latter, it we take into account fibre-length irregularity as well. This would appear to imply that the effect of fibre-length irregularity on the spinning capacity of a cotton is insignificantly small. It must, however, be remembered that, even without taking into account this fibre-property, the values of the multiple correlation coefficient between the highest standard warp counts and mean fibre-length and fibre-weight per in. are very high for both series of samples (·906 and ·937 respectively). In order, therefore, that the inclusion of any other fibre-property may further raise these values, its influence on the spinning capacity must at least be compatible with that of mean fibre-length or fibre-weight per inch—a feature which admittedly is not enjoyed by fibre-length irregularity. The important fact shown by these 30 samples is that in order to bring out the true significance of fibre-length irregularity, it is necessary to employ cottons with as wide a range of fibre-properties as possible, lest as in the case of the Standard Indian Cottons possessing a narrow range of properties, its full import may be masked by other factors.

Comparison with an Earlier Method

As mentioned above on page T55, the only impersonal method known to us for estimating the dispersion of fibre-length in a cotton is the one described by Miss Clegg[6] in a recent issue of this *Journal*. In this method two quantities called the "percentage short fibres" and "percentage dispersion" are obtained as a result of a rather elaborate construction on the Baer Sorter diagram of a cotton. Of these the former is very much more akin than the latter to our fibre-length irregularity, as will be seen from Table VI, which gives the results of applying the two methods to six Indian cottons.

It is interesting to observe that according to both methods, so different in their technique, these six cottons are placed in the same order as regards staple irregularity. It will be further seen that the values of fibre-length irregularity are uniformly higher than those of "percentage short fibres." This may be a point in favour of the former in the following way. It is highly

Table VI

Values of Fibre-length Irregularity (%) and "Percentage Short Fibres" for Indian Cottons

Season	Cotton	H.S.W. Counts	Mean	Mode	Fibre-length irregularity (A and N)	"Percentage Short Fibres" (Clegg)
1929–30	Mollisoni ...	8	0·70	0·72	9·8	3·6
1931–32	A. 19	6	0·67	0·65	11·1	4·6
1929–30	1027	34	0·97	1·02	12·9	5·6
1931–32	Hagari 1 ...	30	0·85	0·90	14·8	7·1
1929–30	Co. 2	28	0·90	0·97	17·0	9·0
1930–31	289 F.	44	0·96	1·04	20·1	12·0

probable that more groups of short hairs than those included in the "percentage short fibres" are responsible for adversely affecting the spinning capacity of a cotton and therefore the fibre-length irregularity may be a more correct estimate of their properties from the practical point of view. Furthermore, the fibre-length irregularity is derived from the length distribution data furnished by a Balls Sorter while the calculation of "percentage short fibres" is based upon the Baer Sorter diagram of a cotton. It is well known that, although in the hands of an experienced worker, the Baer Sorter is capable of giving quite accurate results, the chances of errors of personal judgment creeping in the results are rather more for this apparatus than for the Balls Sorter. Where only a Baer Sorter is available, Clegg's method will give useful information regarding the percentage of short hairs in a cotton; where both types of apparatus are available, the calculation of fibre-length irregularity from the Balls Sorter data is likely to yield results less influenced by personal judgment of the operator.

ACKNOWLEDGMENT

We wish to express our thanks to Mr. V. Venkataraman for preparing some of the tables and calculating the correlation coefficients used in this bulletin.

REFERENCES

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[3] Gladys G. Clegg. "The Stapling of Cottons. Laboratory Methods in use at the Shirley Institute 1931" Journal of the Textile Institute, T35, 1932.

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[5] *Ibid.*

[6] Gladys G. Clegg. *Ibid.*

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3—THE INFLUENCE OF WARP TWIST ON END BREAKAGE DURING WEAVING

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INTRODUCTION

The object of the experiment described in this paper was to find out to what extent deviating from normal practice in the matter of warp twist would effect end breakage rate, and consequently weaving efficiency, in automatic weaving.

Since it was highly desirable that the experiment should be carried out under mill conditions, it was arranged through the kindness of the late Mr F. Arrowsmith and the board of the company for both the spinning of the yarn and the weaving of the cloth to be carried out at the mills of the Eccles Spinning and Manufacturing Company, Patricroft; and it is opportune here to express our appreciation for the valuable advice and assistance given by him and the members of his staff.

The weaving trial itself was made on four 36-in. reed-space model E type Northrop automatic looms fitted with Roper let-off motions. The main concern was to compare the behaviour of four sets of warps in which the twist constants were varied from 3·5 through 4·1 and 4·5 to 5·0, when weaving a fairly good quality Burnley printer of particulars 36s/40s, 63/64. For the second half of the experiment, in order to obtain a cloth of better cover, this construction was changed to 63/75, the count of warp and weft remaining the same. It might further be added that although originally intended to be 30½ in. wide, the cloth was actually made only 28½ in. wide in order that it could be finished in the College Dyehouse.

YARN SPINNING AND WARP PREPARATION

The whole of the yarn required for the experiment, both warp and weft, was specially spun for the purpose. The four lots of warp were spun successively on the same ring frame, the twist constants being taken in the order 4·1, 4·5, 5, and 3·5. The spindle speed was maintained at 9·350 r.p.m. throughout the spinning, and the varying twist obtained by changing the front roller speed.

For all the yarn, the cotton used was American of approximately one inch staple, but since they were not all spun under identical conditions, no useful purpose would be served by analysing the results of end-breakage observations.

In the winding process, the yarn with the twist constant of 3·5* was wound at the same tension as the 4·1, but for the 4·5 and 5·0 yarns the drag on the spindle wharve was increased slightly in each case. In winding, as also in beaming, all knots were tied with a Barber knotter. No trouble was experienced in the beaming except in the case of the last back beam of the 4·1 yarn, where several ends ran off the bobbin before the beam was completed. In all, five back beams, 1,000 yards in length, 382 ends per beam, were made from each twist constant, so that four weaver's beams of each 242 yards long, were available for the weaving test.

The sizing was the only operation in the whole of the experiment that was not supervised by one of us†, and no details can be given. All that can be said is that instructions were given to size all the yarns equally, with whatever percentage of size was normally used in the shed. Tests made subsequently on the cloth, however, showed that differences in the size content did exist, the results being as follows—

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* Hereafter the warp yarns will be referred to simply by the twist constant used.
† A. Pollard.

3·5	9·7%	4·1	12·4%	4·5	11·2%	5·0	10·6%

Thus, the 4·1 warps were more heavily sized than the others.

THE WEAVING TEST AND THE RESULTS RECORDED

The looms used were four which had been selected by the weaving manager as being in good condition and as nearly as possible alike in their weaving characteristics. These were disposed beam to beam, *i.e.* one behind the other; and the order of weaving was arranged so that the four twist constants were woven simultaneously, and also so that each loom wove one warp of each twist constant. In this way the effects of atmospheric variations and loom differences were reduced to a minimum.

Since the warp breakage rate was the sole concern of the test the weft changing mechanism was operated from the weft fork, the weft used being the same throughout. During the test the number of warp breakages in each loom were recorded every hour, together with the cause of each breakage and the position in the warp where it occurred.

The test lasted from 11.15 a.m. on 13th November 1929 until 2.15 p.m. on December 17th, and the total time for which the looms were under observation was 135 hours in each case, divided among the four sets of beams as follows—

	1st set	2nd set	3rd set	4th set	Total
Hours.	33	34	36	32	135

During this time there were stoppages due to causes that were not related in any way to the behaviour of the warp, and for the purpose of assessing the relative behaviour of the warps the time so lost should be deducted from the gross weaving time. See Table I.

Table I—Weaving Times

	3·5	4·1	4·5	5·0
Gross weaving time, hours ...	135	135	135	135
Time lost for reasons other than end breakage ...	3¾	¾	1½	1
Nett weaving time, hours ...	131¼	134¼	133½	134

The longest individual stoppage was one of 3½ hours on November 26th in the case of loom No. 6 which was weaving the 3·5 warp at the time. The cause was a smash due to an accident whilst filling the weft battery. Other stoppages were due to such items as insertion of wrong weft, unweaving a thin place, rectifying a mechanical defect, and making repairs to the loom.

The number of warp breakages which occurred are shown for the different twist constants in Table II together with the average breakage rate per loom per hour which are also plotted in Fig. 1.

Table II—Warp Breakages

Twist Constant	Total Breaks	Nett weaving hours	Breaks per loom per hour
3·5	154	131¼	1·17
4·1	147	134¼	1·09
4·5	118	133	0·89
5·0	65	134	0·49

These results are analysed in Table III to show the relative behaviours of the four twist constants in each of the looms used. Table IV shows how they stand in relation to the time when woven.

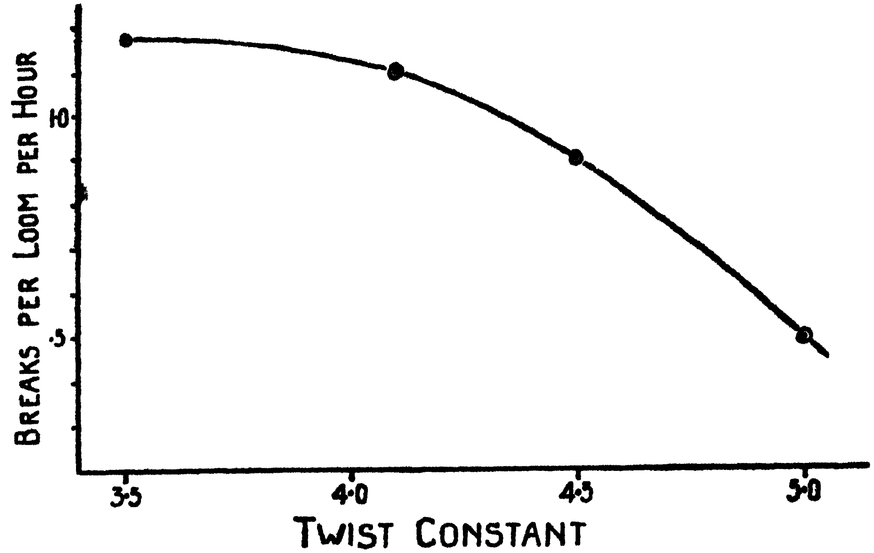

FIG. 1

Table III—End Breakages per Loom

Twist Constant	Loom Number 5	6	7	8	Totals
3·5	49	27	37	41	154
4·1	47	39	36	25	147
4·5	29	25	36	28	118
5·0	14	17	15	19	65
Totals	139	108	124	113	484

Table IV—End Breakages per Set

Twist Constant	1st Set	2nd Set	3rd Set	4th Set	Totals
3·5	49	27	37	41	154
4·1	25	47	39	36	147
4·5	36	28	29	25	118
5·0	17	15	19	14	65
Totals	127	117	124	116	484
Average breaks per loom per hour ...	0·96	0·86	0·86	0·91	

As is to be expected the smaller groupings of the results show some differences among themselves; but the figures provide no grounds for suspecting that any particular twist constant had received preferential treatment of any importance by virtue either of the interplay of the loom and atmospheric factors, or of possible differences in the reaction of the various warps to these factors. In addition, as indicated by the figures given in Table IV for the average breaks per loom per hour, there seems to have been no significant increase in the breakage rate in the 3rd and 4th sets due to increasing the picks from 64 to 75.

It is necessary to record, however, that two other conditions had exercised a detrimental effect on the results for the 4·1 yarn. Firstly, when in loom No. 5 a number of breakdowns were due to ends coming up broken from the beam; and secondly, when in loom No. 6 there was evidence of brittleness in the warp, which may have been caused by overdrying in the Slasher.

Yet, taking these things into consideration, there is no escaping the conclusion that increasing the twist in the warp has very considerably reduced the number of breaks per loom per hour. On the face of it, it would seem that by increasing the twist constant from the normal (4·1) to 5·0, the warp breakage has been halved; but as stated above some allowance has to be made for the adverse conditions under which two of the 4·1 warps were woven. It does not necessarily follow that similar results could be obtained using other qualities of yarn under other conditions; but at least it may be said that the results obtained in the present case are extremely interesting, and indicate that where conditions are otherwise not unfavourable to the use of harder twist, *ad hoc* tests of a similar character might yield results of considerable economic value.

It may be added that the humidity in the neighbourhood of the looms was observed at the mid point of every hour throughout the weaving, and was found to have been fairly constant throughout in the region of 86 per cent. The records so made have been examined to see whether any relation existed between the atmospheric condition and the total number of breaks occurring during each interval, but no significant trend could be found.

DETAILED ANALYSIS OF WARP BREAKAGES

In Table V are given the causes of the breaks so far as it was found possible to identify and classify them.

Table V—Causes of Warp Breakages

Twist Constant	3·5	4·1	4·5	5·0	Total	% of Grand Total
Lumps... ...	17	12	9	0	38	7·8
Snarls	4	7	6	7	24	5·0
Knots	4	6	6	0	16	3·3
Soft Places ...	14	5	8	4	31	6·4
Broken on beam	3	15	7	1	26	5·4
Taped ends ...	9	9	8	7	33	6·8
Unaccounted ...	103	93	74	46	316	65·3
Grand Total ...	...	...	...	...	484	100·0

The term "lumps" used in the first line of the Table applies to relatively large pieces of size which had accumulated round slubs or collections of loose fibre on the yarn surface. These offered resistance to passing through the stop motion and healds, and would consequently be subjected to local abrasion. Continued failure to pass the obstruction would result in steadily increasing extension of the yarn in front of it until rupture occurred. In those cases recorded under this heading the break took place in the immediate vicinity of the "lump," though not necessarily while still being restrained by the obstruction. In some cases the latter were eventually passed, but local weakening due to abrasion had evidently been sufficient to cause final breakdown before the fell of the cloth was reached. As might be expected, increasing the twist—and thereby reducing the amount of loosely bound fibre on the yarn surface—materially reduced the number of failures due to this factor; but taking all the warps together, the proportion of the total breaks that could be directly ascribed to "lumps" was only small (7·8 per cent.).

It is worth noting that the increase of twist does not seem to have materially affected the number of breaks due to snarls. This does not necessarily mean, however, that the number of snarls did not increase, because it may have been that simultaneous changes in other yarn characteristics helped to get them through the weaving operations.

Breakages due to knots and taped ends showed no definite trend as the twist constant changed, and together accounted for 10·1% of the total. Weaknesses due to soft twist, as might be expected, were prominent only in the 3·5 warp; while in the figures for ends broken on the beam are shown the defects in the 4·1 warp already mentioned.

It is in the "unaccounted" group that interest chiefly lies. The breakages that are recorded in the Table under this heading were originally intended to have been treated in two groups. The first group was to have referred to those breakages for which the reason was known but which were due to such a variety of causes that separate classification would be profitless. Among such causes may be mentioned chipped shuttles, crossed ends, and broken and rough healds. The other group was then to have referred exclusively to those breakages which could not be ascribed with certainty to any particular cause. It is much to be regretted, however, that the records for these two groups were mistakenly confused, so that it was only possible to classify them under one head. Fortunately, little or no harm was done; for the number of breaks which would have fallen in the first group is known to have been small compared with that of the unaccounted breaks. In any case it is only reasonable to regard the incidence of such defects as broken healds and chipped shuttles as being entirely independent of the twist in the warp; so that their effects are likely to have been roughly the same for all the warps. The significant fact is that the "unaccounted" figures show a pronounced fall in the number of breakages as the twist constant increases. Further, those breakages due to what might be called abnormal stresses of weaving have been largely accounted for under other heads. Thus the evidence seems to indicate that the bulk of the failures were due to normal stresses of weaving, and that the differences between the various twist constants ought to be explainable for the most part in terms of the physical properties of the yarns.

THE YARN TESTS

Tests for breaking load and extension were made on both sized and unsized yarns. The results are given in Table VI.

Table VI

Twist Constant	3·5	4·1	4·5	5·0
Lea breaking length ...	1641	1818	1673	1589
S.T. strength, unsized (oz.)	6·94 ± 0·09	8·11 ± 0·09	7·98 ± 0·10	7·8 ± 0·10
S.T. strength sized (oz.)	8·7 ± 0·11	9·2 ± 0·11	8·85 ± 0·11	8·94 ± 0·11
Mean deviation of unsized B.L.	1·07	1·11	1·23	1·19
Mean deviation of sized B.L.	1·29	1·28	1·31	1·34
Extension at break unsized (in.)	1·10 ± 0·009	1·02 ± 0·007	1·11 ± 0·009	1·21 ± 0·009
Extension at break sized (in.)	0·59 ± 0·008	0·62 ± 0·007	0·64 ± 0·009	0·74 ± 0·007

The figures for breaking length are the means of 120 lea tests, one from each of 120 bobbins taken at random from each lot of yarn.

In making the single thread tests the primary object in view was to obtain a measure of the extension properties of the four yarns, and for this purpose the Shorter & Hall autographic tester was used with a test length of 11 inches. It was decided that 100 tests would be enough to give a sufficiently accurate mean in each case. In this connection, and in so far as breakages may be directly due to lack of strength or extensibility, it should be pointed out that the responsible weaknesses occur only at very rare intervals. For example, in the present case, one break per loom per hour means that on the average the equivalent of something like 10,000 yards of a single end is woven before a breakage occurs. Thus directly to compare the four yarns concerned for such infrequently occurring weaknesses would probably mean that several hundred thousand ordinary single thread tests would have to be made in each case. It is only possible, therefore, to relate the warp breakage rates to the present yarn tests by more or less indirect inference.

Taking first the lea test results, it is clear that yarn strength as ordinarily measured in the industry bore no relationship whatever to weavability. The 5·0 yarn, though 12½% weaker than the 4·1 yarn has approximately half the number of warp breakages. It remains a matter of doubt, however, as to whether the difference in strength is not due, at least in part, to changes in the properties of the lea rather than of the yarn itself. This might be the case if the less hairy surface of the 5-0 yarn were such as to make it easier for the broken loops of yarn to slide past one another during the test. But however this may be, there are certainly no grounds for supposing that the 5·0 yarn had a *smaller* proportion of weak places which could account for the better weaving. Rather the reverse, as is indicated faintly by the single thread strengths and their mean deviations.

In the unsized state the yarns show changes in single thread strength of the same kind as is evidenced in the lea test results, though the decrease with twist constants higher than 4·1 is not so pronounced nor, indeed, is it significant. Sizing has resulted in an all-round increase in strength especially in the 3·5 yarn, but now the other yarns do not show even a uniform fall in strength as the twist increases. The small number of tests made is no doubt responsible for this, but even so it is permissible to assert that in the sized state the 5·0 yarn was at most no stronger than the 4·1 yarn, a fact which is significant from the point of view of the warp breakages. So far as the yarn tests are concerned, therefore, it remains only to consider the extension results.

In the unsized state the yarns behaved in a manner similar to that observed by numerous other workers. The 3·5 yarn gave a high value owing to fibre slippage in the fairly frequently-occurring soft and weak places. In the 4·1 yarn a lower value was recorded, fibre slippage having ceased to dominate the situation; and from there on the extension increased owing to the increasing angle of twist. After sizing, the fibre slippage in the 3·5 yarn was largely eliminated, hence a progressive increase in extension was shown throughout the range of twist, though of course on a lower level.

The absolute differences in sized breaking extension are small, and at first sight would seem incapable of being responsible to any extent for the differences in end breakage during weaving. It may be shown, however, that even these small differences are more important than they seem

If we assume that for all the sized yarns the stress-strain relationship is represented by a straight line* we can derive the following values for the load in ounces corresponding to unit extension.

Yarn	3·5	4·1	4·5	5·0
Breaking load Extension at break ...	14·7	14·9	13·7	12·1

Taking the 4·1 and the 5·0 yarns, to which attention is particularly directed by the end breakage results, it will be seen that, for any given degree of stretch which may be imposed during weaving, the tension in the former will be on the average about 23% greater than that in the latter.

In the Northrop loom, with a positive let-off motion, the beam does not oscillate as it does in an ordinary Lancashire loom. Nor is there a vibrating back-rest to compensate for the deflection of the threads during the formation of the shed. Hence the opening of the shed puts the yarn in tension to an extent which depends on its stress-strain properties. If, of two yarns, one is less extensible than the other, then the stretching demanded by the opening of the shed will induce a higher tension in the former than in the latter. Therefore, as in the present case, even though the less extensible yarn were slightly stronger than the other, it would still suffer a greater number of breakages.

LOCATION OF WARP BREAKAGES

In Table VII the breaks are classified according to the position in the warp where they occurred.

Table VII—Location of Warp Breakages

Twist Constant	Between beam and back rest 11 in.		From back rest up to and including stop-motion 13¼ in.		From stop motion to cloth fell 19¾ in.		Total
	No.	%	No.	%	No.	%	
3·5	42	27·2	12	7·8	100	65·0	154
4·1	22	15·0	14	9·5	111	75·5	147
4·5	21	17·8	11	6·2	86	72·0	118
5·0	0	0·0	4	6·1	61	93·9	65
All warps ...	85	17·5	41	8·5	358	74·0	484
All warps per in. of warp	7·7		3·1		18·1		—

Since the three divisions of the warp were not equal, in the last line of the Table a correction has been made in respect of the breaks in all the warps.

It is first to be noted that most of the breakages took place between the stop-motion and the fell of the cloth. The fact that the abrasion by healds and reed operates in this section no doubt largely accounts for this; but not entirely, for there is another circumstance that has to be taken into consideration. Owing to the healds not being centrally disposed between the fell and the beam, the tension due to shedding is not uniform throughout the whole stretch of warp. If it were possible to eliminate all friction between the yarn and the heald-eyes, drop wires and back rest, uniformity of tension would be obtained; but as things are the tension is at a maximum between the fell and the healds, and drops by stages as it passes each point of friction towards the beam. The extent to which it falls from the front to the back of the loom depends on the degree of friction at these points, especially at the healds, but it is not known whether there was any difference in this respect between the four kinds of yarn used in the present experiments.

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* It is true that in fact the stress strain curves are not straight lines, but they are nearly so and there is no appreciable difference in the work factor as between the different yarns. The general argument, therefore holds good. In this connection it may be of interest to note that whereas the curves for all the unsized yarns were generally convex with respect to the extension axis, those for the sized yarns were concave.

On the other hand, the different yarns will certainly have suffered from actual abrasion in the healds to a varying degree. Because of the non-central position of the healds, the ends are subjected to a slight back and forth movement through the heald-eyes at each opening of the shed in addition to the general forward movement as weaving proceeds. But the amount of abrasion that takes place depends on the coefficient of friction between the two surfaces and on the pressure between them; so that here also we have conditions that are favourable to the warp yarn which has a high strain stress ratio. The higher this ratio, the lower the tension; the lower the tension the less the pressure between yarn and heald-eye, and the less the abrasion.

The numbers of breaks recorded for the middle sections of the warps are relatively small, but here again there are indications that an increase of twist is advantageous. That the numbers are small, however, does not necessarily mean that the stop-motion has had but little detrimental effect on the yarn, because it is possible that damage initiated at that point did not show itself until aggravated in the later stages. What abrasion there was at the back-rest was not likely to have produced any measurable deterioration.

In the section between the beam and the back-rest there were more breakages than in the middle section. Here there are no frictional contacts to complicate the conditions. The breakages recorded constitute the straightforward elimination of the really weak places by direct tension, and include the majority of the ends broken on the beam. That some of the latter carry forward into the middle section before the loom is stopped is shown by the figures for the 5·0 warp.

If the ends broken on the beam could be deducted from the figures for this section, the results would probably not show a regular improvement with increasing twist. Nevertheless, it is clear that the 5·0 warp was markedly superior to the 3·5 warp. This would seem to suggest that, in addition to reducing the tension imposed during weaving, the increased twist has been beneficial in reducing the number of "soft twist weaknesses." Some indication of this has already been given in Table V, where the number of breaks known to have been due to soft twist are recorded. It should be pointed out, however, that it was not always an easy matter to decide when a break was due to soft twist and when it was not. When there was any doubt, the break was classed as unaccounted. Hence it is exceedingly probable that in reality the number of defects due to undertwisted places, as well as the advantage of increased twist in that connection, was greater than the analysed results have shown.

So far as the effects of the beat-up are concerned, it would appear that the extension properties of the yarns can have been of very little, if any, account. During the beat-up, each pick exerts a pull on the warp to an extent depending on the friction between the two sets of threads. This frictional resistance increases from a minimum at the commencement of the beat-up to a maximum at the moment the pick is finally in place. Hence the reaction on the warp threads is simply one of increasing tension. The frictional resistances to the beat-up in the case of the four yarns here under discussion are not known, so discussion on this point cannot be carried very far. Even so it does not seem likely that the differences between them will have been appreciable; and, if anything, they are likely to have reacted detrimentally on the harder twisted yarns.

The foregoing consideration of the question does not apply, of course, to cloths of heavy construction, for in their case the situation is somewhat complicated by the fell of the cloth actually moving forward slightly under the impact of the reed, and receding again immediately afterwards.

SUMMARY OF RESULTS AND CONCLUSIONS

The results obtained and conclusions arrived at as a result of the experiment may be summarised as follows—

(1) Increasing the twist in the warp yarn up to a twist constant of 5·0 brought about a considerable reduction in the number of end-breakages, in spite of the fact that the yarn strength as measured by the lea test was thereby reduced. Therefore,

(2) Lea strength cannot be regarded as a satisfactory criterion of weavability.

(3) The extension at break was increased to a small, but nevertheless important, extent. In consequence, the decrease in end-breakage may be attributed, at least in part, to
   (*a*) decreased warp tension during shedding, and
   (*b*) less abrasion in the heald-eyes.

(4) Another factor which in all probability affected the end-breakage results to a considerable extent was the tendency of increased twist to eliminate weaknesses due to local conditions of soft twist.

Table VIII—Fabric Tests

	Warp Twist Constant			
	3·5	4·1	4·5	5·0
63×64 *Construction, sized*				
B.L./2 in. width (warp), lb.	50·3	55·5	58·4	57·0
,, ,, (weft), lb.	34·1	37·3	43·7	38·1
Extension at break (warp)	7·7%	7·8%	8·1%	9·2%
,, ,, (weft)	24·8%	23·4%	24·0%	22·0%
63×75 *Construction, sized*				
B.L./2 in. width (warp), lb.	52·2	56·5	56·9	58·1
,, ,, (weft), lb.	40·5	46·5	48·9	44·6
Extension at break (warp)	7·3%	8·2%	8·9%	8·9%
,, ,, (weft)	25·4%	27·0%	25·0%	25·7%
63×64 *Construction, desized*				
B.L./2 in. width (warp), lb.	50·1	*47·0	45·2	52·6
,, ,, (weft), lb.	31·5	*37·4	32·2	40·3
Extension at break (warp)	16·6%	*13·7%	16·4%	20·6%
,, ,, (weft)	21·6%	*21·3%	20·1%	24·1%
63×75 *Construction, desized*				
B.L./2 in. width (warp), lb.	47·9	49·0	48·6	—
,, ,, (weft), lb.	56·0	48·4	51·5	—
Extension at break (warp)	10·7%	10·3%	11·8%	—
,, ,, (weft)	19·6%	19·4%	21·8	—

* Mean of 8 Tests

APPENDIX

TESTS ON THE CLOTHS PRODUCED

In view of the increased weaving efficiency obtained with higher twist, and in spite of lower warp yarn strength, a certain amount of interest attaches to the breaking loads and extensions of the fabrics produced. These are given in Table VIII. The figures for the sized breaking loads are the means of 16 tests in each case, and for the unsized 12 tests, except where otherwise stated.

It is not proposed to discuss these figures here in any detail; but it is noteworthy that the increase in twist has not produced any marked change in the breaking load. With the increase of twist constant from 4·5 to 5·0 there is no considerable fall in strength as observed in the lea test results. Rather do the fabric strengths follow the changes already recorded in the single thread tests. (cf. Table IV). In extension, the warp way results show an increase with increase of twist which is comparable to that observed for the single threads.

FINISHING

Thanks to the generous co-operation of the Bradford Dyers' Association and the Bleachers' Association, some 500 yards of each of the 4·1 and 5·0 cloths were finished in various ways—back-filled and dyed; mercerised, schreinered and dyed; mercerised and dyed; and plain dyed. In the case of the last two the pieces were measured before and after treatment, and the gains in length were as follows—

Dyed and Mercerised

4·1	Gain in length	4·9%
5·0	„ „	3·6%

Dyed, ordinary finish

4·1	Gain in length	3·25%
5·0	„ „	1·8%

As is to be expected, therefore, fabrics made from the harder twisted warp would have to be specially adjusted for pick and length in order to finish to the desired finished particulars.

It is not suggested that of these two fabrics, that with the harder twisted warp could be tendered against the other, because the differences in handle and appearance, though slight, are none the less apparent. Nevertheless the former gave a good, uniform, clear finish and a crisp handle which for certain purposes would be definitely an advantage. In cloths having a predominantly weft face, such as sateens, and in pile fabrics such as Terry towelling, the harder twist could probably be used without any apparent effect on the finished article.

The authors wish to acknowledge the valuable help and advice given by Mr D. M. Hollins (British Northrop Loom Company), and Mr W. A. Hanton, throughout the experiments herein described, and the no less valuable assistance of Mr E. Slattery, in the carrying out of many of the tests.

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Received 15/9/33

4—COMPARISON OF THE CLOTH QUALITIES OF CONTINENTAL AND NOBLE COMBED MATERIALS*

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(Department of Textile Industries, Bradford Technical College)

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INTRODUCTION

It is the purpose of this and subsequent investigations to place the worsted textile industry in possession of facts bearing upon the preference which has been displayed for certain types of worsted yarns and cloths of Continental manufacture. Shortly after the outbreak of war, a report was presented based on the analysis of over 300 samples of German made worsted cloths. The opinion was put forward that the most striking difference between the Bradford and Continental methods of producing worsted yarns and cloths was to be found in the use of shorter wools and the method of preparing, combing, drawing and spinning, and it was therefore suggested that some systematic inquiry into these factors should be instituted. This led to the inauguration of a series of investigations, the first being a comparison of the properties of worsted yarns manufactured by the various methods,† and as anticipated, the results afforded a valuable basis for discussion and further investigation.

INVESTIGATION II

Comparison of the Cloth Qualities of Continental and Noble Combed Materials

An investigation regarding the cloth qualities of the Noble and Continental combed products is a natural corollary of that relating to drawing and spinning methods.

The material employed for this purpose was typical of those consumed on the Continent in pre-war times. Both combs have been utilised to their utmost capacity in the production of a "clear" top. As the Continental comb produces the greater yield of top to noil, the presence of shorter fibre in the product of this machine will, it is anticipated, produce yarn and cloth possessing different qualities to those contained in Nobel combed material.

This investigation was conducted under the auspices of the British Research Association for the Woollen and Worsted Industries (now Wool Industries Research Association), and commenced October 1917. A Committee, consisting of the following gentlemen, was elected to decide upon the scheme of work, and supervise the same—

Combing Section of Textile Industry—Messrs. H. Firth (M. Firth & Co. Ltd., Woolcombers), E. Foster (Prince Smith & Sons, Combing and Spinning Machine Makers), H. Peel (Robinson & Peel, Recombers), A. E. Raper (Isaac Holden & Sons, Woolcombers).

The British Research Association for the Woollen and Worsted Industries—Messrs. J. Crowther, G. Garnett, Ald. J. P. Hinchcliffe, and Ald. P. R. Jackson.

Technical College—The Chairman of the College Committee, the Principal of the College, and the Lecturer in Preparing, Combing, and Spinning; the writer acting as Convener.

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* Originally issued in 1919 as a Confidential Publication (No. 5B) by the Wool Industries Research Association.

† "Investigations of the Influence of the Various Methods of Manufacturing Worsted Yarns on Single and Two-fold Twist Warp Cloths: (*a*) Clear finished, (*b*) Milled finished." —*J. Text. Inst.*, 1917, **8**, 102–123.

Raw Material

After consideration and examination of many samples of material it was decided to purchase four bales (1,292 lb.) of Cape Merino wool, nine months' growth, at 23¾d. per lb.

Classification of Material—The material was sorted as follows—

First quality ...	1,059 lb.
Second quality ...	220 lb.
Skirtings	13 lb.
	1,292 lb.

The first quality only, 1,059 lb., being employed for investigation.

Scheme of Work

The plan of the investigation is indicated by the following diagram—

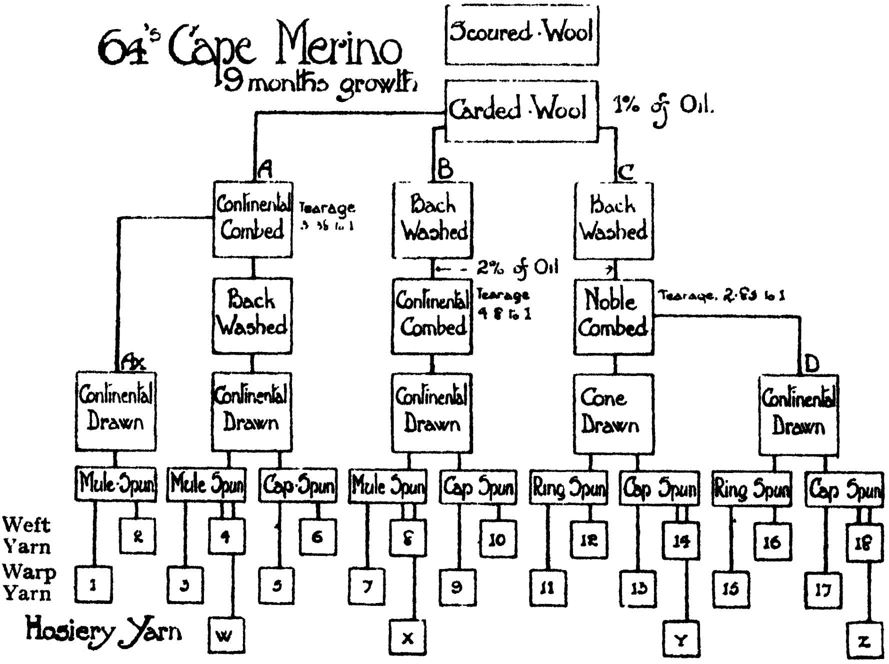

FIG 1

After scouring and carding, the material was divided up into such weights as to provide the most suitable conditions for each process and dealt with as follows—

A	Continental combed and backwashed, Continental drawn	Mule spun^{K} Cap spun
Ax	Continental combed and unbackwashed, Continental drawn	Mule spun
B	Backwashed and Continental combed, Continental drawn	Mule spun^{K} Cap spun
C	Backwashed and Noble combed, cone drawn (200 lb.)	Ring spun Cap spun^{K}
D	Backwashed and Noble combed, Continental drawn	Ring spun Cap spun^{K}

Resulting in nine types of worsted warp and weft yarns, each of which was produced in—
(*a*) 2/40s warp (15×11 turns).
(*b*) 1/20s weft (10 turns).

Hence nine lengths of cloth, each of which was cut into three parts in order that a length of each might be obtained in—

(*a*)	Clear finish	Finisher A.
(*b*)	Milled finish	
(*c*)	Clear finish ...	Finisher B.

Hosiery Yarns—By the four methods of manufacture marked ^{K} hosiery yarns 2/20s (7×4 turns) were produced and knitted into vests.

Supervision

(1) The Committee met during the periods of scouring, carding, combing, and drawing processes in order that they might supervise the same.

(2) Messrs. Peel and Firth loaned skilled operatives for sorting, carding, Noble and Continental combing.

(3) Samples of combed tops in each instance were submitted to the Committee before proceeding with bulk.

Scouring

No. of Bowl	Capacity	Temperature
1	1,400 galls. ...	... 125° F.
2	900 galls. ...	... 120° F.
3	700 galls. ...	... 115° F.
4	900 galls. ...	... 120° F.
5	700 galls. ...	... 115° F.

Soap and alkali solutions=5% strength.
Soap used—46 lb. hard oleine.
Alkali used—31 lb. 58% soda ash.

Report

Very satisfactory in colour, handle, openness, etc.

Carding

Card clothed for average 58s quality.
Swifts 125/12s and 140/13½s.
Workers 130/12s and 145/14s.
Doffers 130/12s and 150/14s.
Settings—Initial 24 gauge.
Final 30 gauge.
1% Best olive oil applied=4½ lb.

Started on newly fettled card. Swifts and complementary rollers, workers and doffers fettled midway. General result very satisfactory.

Combing, etc.

I—*Material A—Continental Combed and Backwashed.*

Material Ax—Continental Combed only.

(*a*) *First Intermediate Gilling for Combing* (Material A and Ax).
Two operations through first Botany finisher.
Pins per 1 in., 16; two rows.
Condition applied.
Draft 2. Sliver 3 ozs. per 5 yds.

The card sliver being very springy and elastic, and fibres short, made it difficult to get a passable sliver, with three of a draft. The faller bar markings were very evident and with the small draft adopted were not entirely removed.*

---

* Developments in the intersector gill box have been made since this work was done in 1919, which make it possible to work up shorter materials into blends for Continental drawing, and which eliminate "barry slivers."

(*b*)	*Continental Combing* (Material A and Ax). Eight ends up of sliver=3 ozs. per 5 yds. Combed sliver=2½ ozs. per 5 yds. Gauge 24. Production 123 lb. 10 hours. Tufts per minute, 100.	Very satisfactory working all through.
(*c*)	*Combing Result* (Material A and Ax, dry). Top A 41 lb. 6 ozs. Top Ax 17 lb. 8 ozs. Noil 17 lb. 6 ozs. Tearage 3·38 to 1	Top %=77·3 Noil %=22·7
(*d*)	*Second Intermediate Gilling for Backwashing* (Material A). One operation through first Botany finisher. Five ends up, draft 2. Resultant sliver 6½ ozs. for 5 yds. Sixteen pins per 1 in., double rows.	Very clear and open top sliver.
(*e*)	*Backwashing after Combing* (Material A). 6½ ozs. sliver, 4 ends up. Temperature of solution in both bowls, 100° F. Temperature of drying chambers, 120° F.	Combed sliver much more difficult to backwash then card sliver, due largely to the less springy nature of the fibres.
(*f*)	*Finishing—Three operations* (Material A). First 2 ends up 3 draft=6 ozs. per 10 yds. Second 3 ends up 3 draft=6 ozs. per 10 yds. Third 2 ends up 3 draft=4 ozs. per 10 yds. Sixteen pins per 1 in. double.	An exceedingly fresh-looking top. Full, free open sliver. Bright and attractive looking. Cleanness very striking compared with Material B (backwashed before combing).

II—*Material B—Backwashed Continental Combed.*
Material C—Backwashed Noble Combed.
Material D—Backwashed Noble Combed.

(*a*)	*Backwashing.* Temp. of solution in both bowls, 100° F. Oleine soap solution 5% strength applied as required. Temp. of drying chamber, 144° F. Draft on gill box, 2¾. Condition leaving drying chamber, 16%. 2% best oleine oil applied=7 lb.	Worked very well and sliver perfectly clean. The colour was exceedingly good.
(*b*)	*Continental Combing.* 2% oil. (Material B.) Eight ends up. Sliver 3 ozs. per 5 yds. Combed sliver 2½ ozs. per 5 yds. Gauge 22. 100 tufts per minute. Production, 120 lb. per 10 hours.	A very satisfactory sliver which worked well all through.
(*c*)	*Finishing* (Material B). Two operations—draft 3. Top weight=4 ozs per 10 yds. Faller pins, 16 per inch, double rows.	

(*d*) *Combing Result* (Material B).

Top	50 lb. 1 oz.	Tearage 4·8 to 1
Noil	10 lb. 2 ozs.	
Noil 2nd and 3rd	5 ozs.	

Top %=82·8.
Noil %=17·2.

When compared with Material A the query arises, "Is this superior tearage due to the presence of oil or to the effect of backwashing before combing?" The fact that Material A is dry and Material B carries 2% oil prevents a reliable comparison being made of the effect of backwashing before and after combing.

III—*Material C and D.* 266 lb.

Good clear top.

(*b*) *Noble Combing.* 2% oil.

Punched slivers, 5½ ozs. per 5 yds.
Combed slivers, 1¼ ozs. per 5 yds.
Large circle details. Number of rows of pins, 11. Pins per 1 in., 42 inside row. Set over, 2 in.
Small circle details. Number of rows of pins, 8. Pins per 1 in., 46 outside row. Set over, ⅝ in.
Revolutions per minute, large circle, 3¾.
Dabber brush, 718 dabs per minute.

A larger weight of material would have provided better working conditions and resulted in less noilage.

(*c*) *Finishing* (Material C and D).

First—15 ends up, draft 3=6 ozs. per 5 yds. sliver.
Second—2 ends up, draft 3=4 ozs. per 10 yds. top.

Very fine top slivers; satisfactory working.

(*d*) *Combing Result* (Material C and D).

Top Lot C	146 lb. 12 ozs.	Tearage 2·85 to 1
Top Lot D	50 lb. 0 oz.	
Noil	69 lb. 2 ozs.	

Top %=74.
Noil %=26.

Tearage

A	Continental combed before backwashing	3·38 to 1.
Ax	Continental combed (unbackwashed)	
B	Backwashed, Continental combed in oil,	4·8 to 1.
C D	Backwashed, Noble combed,	2·85 to 1.

Drawing and Spinning

To obtain the best comparative results of the various methods of spinning, cap and ring spinning* have been carried out at Messrs. Thomas Ambler & Sons, Ardsley Mills, Wakefield.

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* Note 1—1/40s yarn was spun from 3 dram roving. 1/20s yarn was spun from 6 dram roving.

Note 2—The material was spun on rings 2 in. in diameter and caps 1¼ in. diameter. These conditions favour the cap spun material.

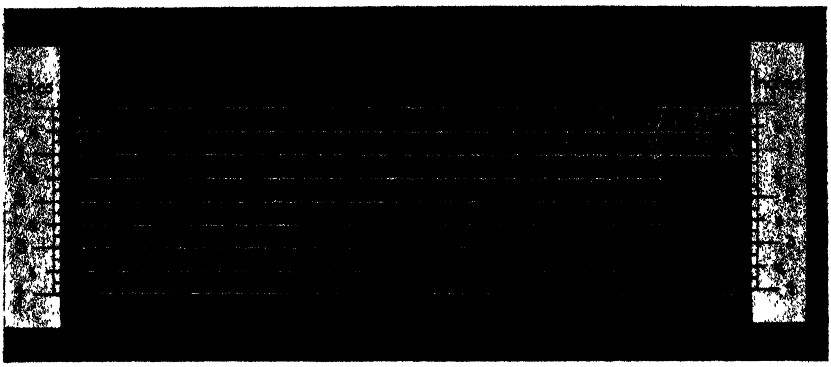

FIG. 2A—Unbackwashed. Continental combed.

FIG. 2B—Backwashed. Continental combed.

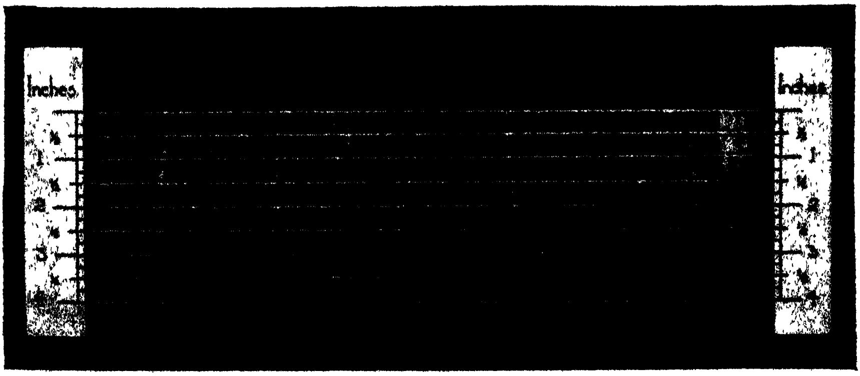

FIG. 2C—Backwashed Noble combed.

Report—In addition to particulars of machines employed, method of working, and behaviour of material in each system of manufacture, the following have been recorded—

(1) Pitch of screws and pins per 1 in. in gills.
(2) The weight in draws per 40 yards behind and before each operation.
(3) Number of operations.
(4) Doublings and draft at each machine.
(5) Diameter and speed of each low front roller.
(6) Speed of spindle at each machine.

Table I Material A—Continental Combed, Backwashed, Continental Drawn, Cap and Mule Spun

DRAWING (CONTINENTAL)

Number of Operations	Machine	Pins per inch	Actual Revs. of Front Roller per minute	Draft	Doublings	Weight per 40 yards. Drams	Comments
1	1st Gill box ...	16	52	3·5	2	200	Worked very well all through
2	2nd Gill box ...	16	52	3·5	2	128	
3	1st Drawing box ...	10	98	3·5	3	101	
4	2nd Drawing box ...	10	98	4·2	2	48	
5	3rd Drawing box ...	12	158	4·06	2	24	
6	Reducer	14	245	4·0	2	12	
7	1st Intermediate ...	17	184	4·0	3	9	
8	2nd Intermediate ...	17	184	4·0	3	6·7	
9	Roving	21	319	4·0	2	3·3	

SPINNING

Material	Type of Frame	Calculated Speed of Spindles per min.	Actual Revs. of Front Roller per min.	Diam. of Front Roller in.	Ratch in.	Calculated Twist	Actual Counts	Comments	
C	Mule	5400	—	$1\frac{1}{16}$	$4\frac{3}{4}$	15	1/41·2s	Very good spin	
C	Mule	5400	—	$1\frac{1}{16}$	$4\frac{3}{4}$	7·5	1/21s	Very good spin	
A	Cap	5800	40	$2\frac{7}{8}$	$4\frac{1}{4}$	15	1/42s	Fair spin	Half iron carriers
A	Cap	5800	78	$2\frac{7}{8}$	$4\frac{1}{4}$	7·5	1/21s	Good spin	
A	Mule (Hosiery)	5400	—	$1\frac{1}{16}$	$4\frac{3}{4}$	7·5	1/21s	Very good spin	
	Twisting—								
	Cap	6444	—	—	—	15 × 11	2/40s	Good working	
	Cap (Hosiery)	6444	—	—	—	7 × 4	2/21s		

Table II Material Ax—Continental Combed, Unbackwashed, Continental Drawn, Mule Spun

DRAWING (CONTINENTAL)

Number of Operations	Machine	Pins per inch	Actual Revs of Front Roller	Draft	Doublings	Weight per 40 yards. Drams	Comments
1	1st Gill box ...	16	52	2·8	2	185	Inclined to stick to top rollers
2	2nd Gill box ...	16	52	3·2	2	128	
3	1st Drawing box ...	10	98	4·0	3	98	
4	2nd Drawing box ...	10	98	4·0	2	48	
5	3rd Drawing box ...	12	158	4·0	2	24	
6	Reducer	14	245	4·0	2	12	
7	1st Intermediate ...	17	184	4·0	3	9	
8	2nd Intermediate ...	17	184	4·0	3	6·6	
9	Rover	21	319	4·0	2	3·2	

SPINNING

Type of Frame	Calculated Speed of Spindles per minute	Diameter of Front Roller in	Ratch in	Calculated Twist	Actual Counts	Comment
Mule	5400	$1\frac{1}{16}$	$4\frac{3}{4}$	15	1/41·2s	Very good spin
Mule	3000	$1\frac{1}{16}$	$4\frac{3}{4}$	7·5	1/21s	

Table III Material B—Backwashed, Continental Combed, Continental Drawn, Cap and Mule Spun

DRAWING (CONTINENTAL)

Number of Operations	Machine	Pins per inch	Actual Revs. of Front Rollers per minute	Draft	Doublings	Weight per 40 yards Drams	Comments
1	1st Gill box ...	16	52	3·5	2	180	No trouble at any operation. Very satisfactory working.
2	2nd Gill box ...	16	52	3·5	2	120	
3	1st Drawing box	10	98	3·6	3	96	
4	2nd Drawing box	10	98	3·8	2	48	
5	3rd Drawing box	12	158	4·0	2	24	
6	Reducer	14	245	4·0	2	12	
7	1st Intermediate	17	184	4·0	3	9	
8	2nd Intermediate	17	184	4·0	3	6·6	
9	Roving	21	319	4·0	2	3·2	

SPINNING

Type of Frame	Calculated Speed of Spindles per min.	Actual Revs. of Front Rollers per min.	Diameter of Front Rollers in	Ratch in.	Calculated Twist	Actual Counts	Comments
Mule	5400	—	$1\frac{1}{16}$	$4\frac{3}{4}$	15	1/41·2s	Very good spin
Mule	3000	—	$1\frac{1}{16}$	$4\frac{3}{4}$	7·5	1/21s	
Cap	5800	40	$2\frac{7}{8}$	$4\frac{1}{4}$	15	1/42s	Fair spin
Cap	5800	78	$2\frac{7}{8}$	$4\frac{1}{4}$	7·5	1/21s	
Mule (Hosiery)	5400	—	$1\frac{1}{16}$	$4\frac{3}{4}$	7·5	1/21s	
Twisting—							
Cap	6444	—	—	—	15 × 11	2/40s	
Cap (Hosiery)	6444	—	—	—	7·5 × 4	2/21s	

Table IV Material C—Backwashed, Noble Combed, Cone Drawn, Cap and Ring Spun*

DRAWING (CONE)

Number of Operations	Machine	Pins per inch	Actual Speed of Spindles per min.	Actual Revs. of Front Roller per min.	Draft	Doublings	Weight per 40 yards Drams	Comments
1	1st Gill box ..	16	—	52	3·5	3	225	Very good working all through
2	2nd Gill box ...	16	-	72	3·5	3	188	
3	6-Spindle gill box		200	60	4·0	3	141	
4	4-Spindle drawing box	—	242	62	4·0	3	105	Some advantage would have accrued from the use of half iron carriers.
5	6-Spindle weigh box	—	242	58	4·0	3	77·8	
6	Finisher	—	746	56	4·2	3	45·5	
7	1st Reducer ...	-	932	70	5·25	2	18·7	
8	2nd Reducer ...		1081	78	5·0	2	7·5	
9	Roving	–	1081	96	5·0	2	3·0	

SPINNING

Type of Frame	Calculated Speed of Spindles per min.	Actual Revs. of Front Roller per min.	Diameter of Front Roller in.	Ratch in.	Calculated Twist	Actual Counts	Comments
Ring	5800	40	$2\frac{7}{8}$	$4\frac{1}{4}$	15	42s	Good spin. Half iron carriers on bottom row.
Ring	5800	78	$2\frac{7}{8}$	$4\frac{1}{4}$	7·5	21s	
Cap	5800	40	$2\frac{7}{8}$	$4\frac{1}{4}$	15	42s	
Cap	5800	78	$2\frac{7}{8}$	$4\frac{1}{4}$	7·5	21s	
Cap (Hosiery)...	5800	78	$2\frac{7}{8}$	$4\frac{1}{4}$	7·5	21s	Iron carriers on top row.
Twisting—							
Cap	6444	- -	—	—	15 × 11	2/40s	
Cap (Hosiery)	6444	—	- -	—	7·5 × 4	2/20s	

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* Since this work was carried out (1919) ring spinning frames have been greatly improved to facilitate the spinning of short wools. For example, among other modifications, the front rollers have been reduced to $1\frac{1}{4}$ in. and $1\frac{1}{16}$ in. in diameter.

Table V Material D—Backwashed, Noble Combed, Continental Drawn, and Ring* and Cap Spun

DRAWING (CONTINENTAL)

Number of Operations	Machine	Pins per inch	Actual Revs. of Front Roller per minute	Draft	Doublings	Weight per 40 yards Drams	Comments
1	1st Gill box ...	16	52	3·2	2	200	
2	2nd Gill box ...	16	52	3·2	2	120	Inclined to stick to top rollers
3	1st Drawing box	10	98	3·9	3	96	
4	2nd Drawing box	10	98	3·8	2	48	
5	3rd Drawing box	12	155	4·0	2	24	
6	Reducer	14	245	4·0	2	12	
7	1st Intermediate	17	184	4·0	3	9	
8	2nd Intermediate	17	184	4·0	3	6·6	
9	Roving	21	319	4·0	2	3·2	

SPINNING

Type of Frame	Calculated Speed of Spindles per minute	Actual Revs. of Front Roller per minute	Diameter of Front Roller in.	Ratch in.	Calculated Twist	Actual Counts	Comments
Ring	5800	40	2⅞	4¼	15	42s	Fair spin
Ring	5800	78	2⅞	4¼	7·5	21s	
Cap	5800	40	2⅞	4¼	15	42s	
Cap	5800	78	2⅞	4¼	7 5	21s	
Cap (Hosiery)...	5800	78	2⅞	4¼	7·5	21s	
Twisting—							
Cap	6444	—	—	—	15 × 11	2/40s	
Cap (Hosiery)	6444	—	—	—	7·5 × 4	2/40s	

Table VI Actual Counts of Warp and Weft Yarns

	Ax	A		B		C		D	
	(1) Unbackwashed	(1) Continental Combed		(1) Backwashed		(1) Backwashed			
	(2) Continental Combed	(2) Backwashed		(2) Continental Combed		(2) Noble Combed			
	(3) Continental Drawn	(3) Continental Drawn				(3) Cone Drawn		(3) Continental Drawn	
Stated counts... ...	Mule 1	Mule 3	Cap 5	Mule 7	Cap 9	Ring 11	Cap 13	Ring 15	Cap 17
Warp 2/40s	2/42	2/44	2/41	2/42	2/41	2/42	2/40	2/41	2/42
	2	4	6	8	10	12	14	16	18
Weft 1/20s	1/21	1/21	1/20	1/21	1/21	1/20	1/20	1/21	1/20

Table VII Actual Counts and Turns per inch of Hosiery Yarns

	A	B	C	D
	Continental Combed Backwashed Continental Drawn Mule Spun	Backwashed Continental Combed Cone Drawn Mule Spun	Backwashed Noble Combed Cone Drawn Cap Spun	Backwashed Noble Combed Continental Drawn Cap Spun
	W	X	Y	Z
Stated Counts 2/20s	2/20s	2/21s	2/20s	2/20s
Stated Twist	*Tests for Actual Turns per Inch*			
7×4 turns per 1 in. ...	3·73	3·808	3·69	3·84

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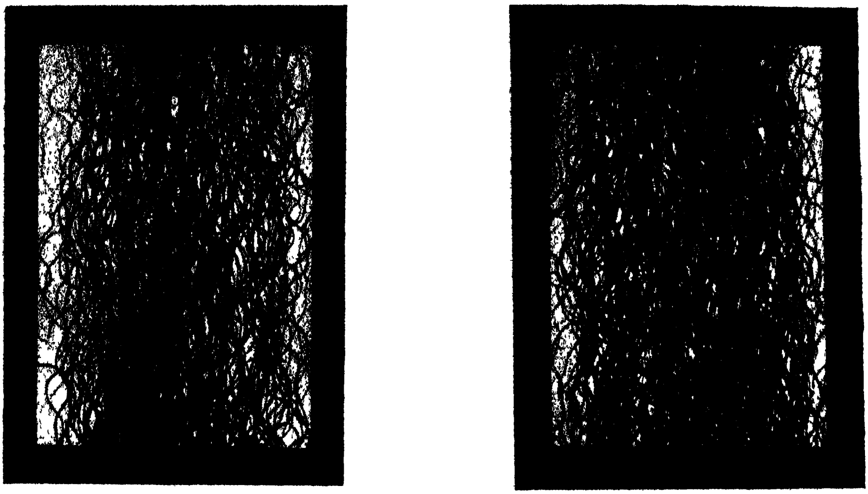
* Since this work was carried out (1919) ring spinning frames have been greatly improved to facilitate the spinning of short wools. For example, among other modifications the front rollers have been reduced to 1¼ in. and 1$\frac{1}{16}$ in. in diameter.

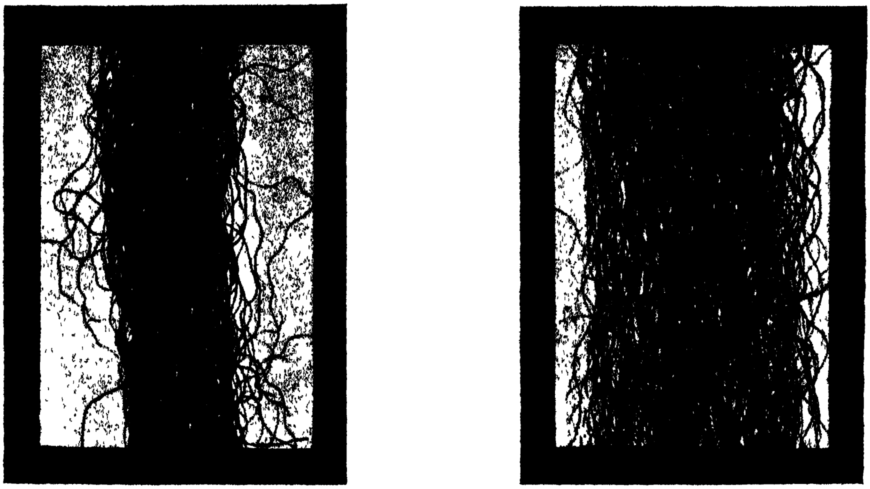
Micrographs—Light through Material

THREE DRAM ROVING—MAGNIFICATION TEN TIMES



MATERIAL A
Continental combed. Backwashed
Continental drawn.

MATERIAL B
Backwashed. Continental combed.
Continental drawn

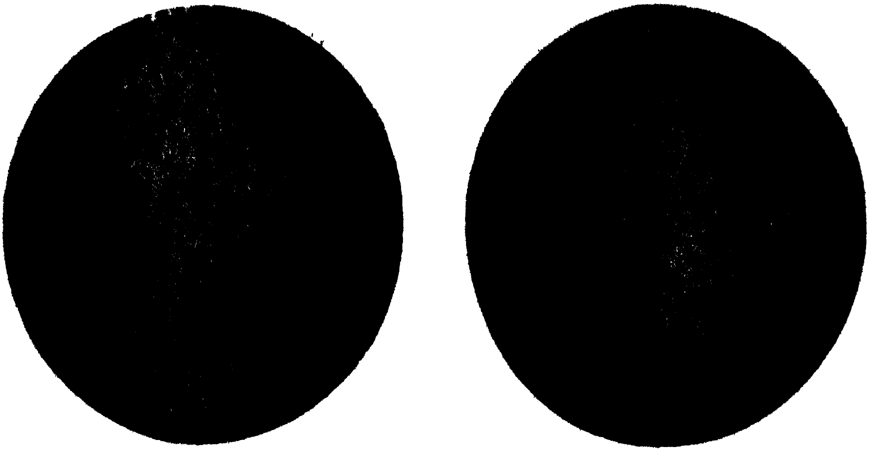


MATERIAL C
Backwashed. Noble combed.
Cone drawn.

MATERIAL D
Backwashed. Noble combed.
Continental drawn.

FIG. 3

Light on Material



Material A
Continental combed. Backwashed.
Continental drawn.

Material B
Backwashed. Continental combed.
Continental drawn.

Material C
Backwashed. Noble combed.
Cone drawn.

Material D
Backwashed. Noble combed.
Continental drawn.

Fig. 4

Table VIII Actual Turns per inch of Warp and Weft Yarns
(Average of 20 Tests)

	Ax	A		B		C		D	
	(1) Unbackwashed (2) Continental Combed (3) Continental Drawn	(1) Continental Combed (2) Backwashed		(1) Backwashed (2) Continental Combed		(1) Backwashed (2) Noble Combed			
		(3) Continental Drawn				(3) Cone Drawn		(3) Continental Drawn	
	Mule 1	Mule 3	Cap 5	Mule 7	Cap 9	Ring 11	Cap 13	Ring 15	Cap 17
Warp (15× 11 turns per 1 in.)	10·18	10·32	10·49	10·75	10·82	10·78	10·73	10·37	10·4
	2	4	6	8	10	12	14	16	18
Weft (7 turns per 1 in.)	6·71	6·56	6·94	6·57	6·44	6·82	6·88	6·49	6·63

Strength and Elongation of the Various Yarns Spun

Prior to testing, each yarn was exposed to an atmosphere, the hygrometer readings of which were uniform, and indicated—Dry bulb, 59° F.; wet bulb, 57·5°; or a humidity of 90 per cent. This was carried out in order that "condition" should be uniform and accurate relative results obtained. The yarns were tested on a Baer's single-thread machine worked by means of an oil plunger regulated to a uniform speed. Tests were made from various parts of the bulk, and each length tested was 18 in. between the clamps. Both strength and elongation cease to be registered immediately the thread breaks. In all cases 20 tests were made and the average taken. In the case of any doubt the series of tests concerned was repeated.

The strength and elongation of the various yarns are indicated and compared in the following illustrations—

Strength of Yarns

Tearage

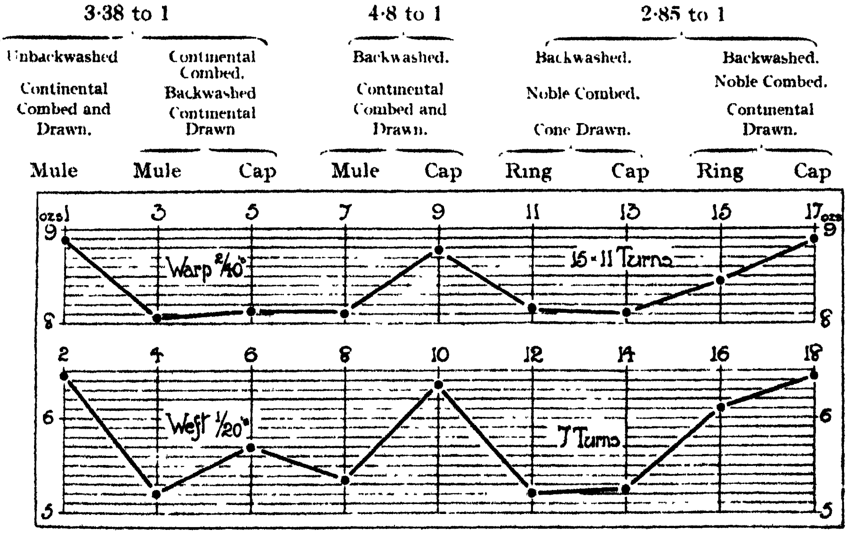


Fig. 5

Elongation of Yarns

Tearage

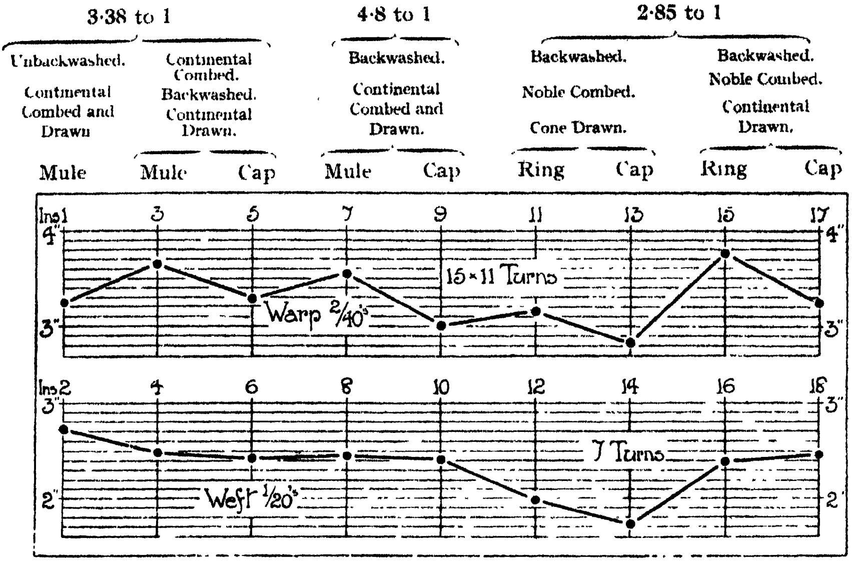


FIG. 6

Strength of Hosiery Yarns (2/20s 7×4 turns)

Tearage

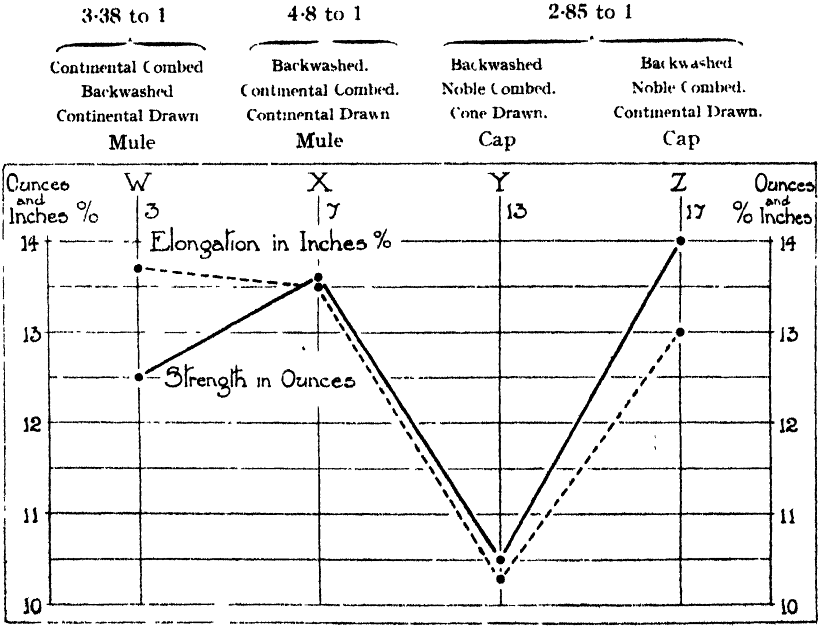


FIG 7

Weaving

The nine warps were woven on identical tappet looms. There was little or no variation in the weaving property of the warps and all were considered "Good".

Cloth particulars—in loom—

Warp 2/40s.	Weft 1/20s.
14s reed 4s.	56 picks per inch.
Weave—2 and 2 twill.	1,916 threads in warp.
Loom width—34 inches.	Grey cloth width—31¾ inches.

Dyeing and Finishing

Each of the nine lengths of cloth woven was cut into three. Two lengths of each were forwarded to Finisher "A", one length for clear finish and the other for milled finish. The third length of each cloth was clear finished by Finisher "B".

In each of the three instances of finish the treatment has been common and simultaneous, thus the results are strictly comparative.

Table IX Width of Cloths

			Finisher A				Finisher B	
			Clear		Milled		Blue Clear	
Cloth No	Loom	Grey	Wet	Finished	Wet	Finished	Wet	Finished
	in.	in.	in.	in	in.	in.	in.	in.
1	34	31⅞–32	30	29½	28½	28¾–⅝	28¼	28½
3	34	31½	29¾	29⅜–½	28½	28¼	29⅛	28½–¾
5	34	31½	29½	29⅝	28½	28⅜–⅝	29⅛	28½–¾
7	34	31¾	29¼	29½	28½	28¼–½	27½–28	28¼–⅜
9	34	31½	29¾	29¼ ½	28½	28¼–⅜	29⅛	28¼ ½
11	34	32	29 ¼	29¼–½	28¼	27⅞–28⅛	27⅞	28¼–½
13	34	31½–⅝	29	28⅞ 29¼	28	28⅛ ⅜	28–¼	28¼–½
15	34	31⅝	29½	28⅞–29¼	28½	28⅜	28½–29½	28⅝–¾
17	34	31½	29½	28⅞–29⅛	28¼	28¼–⅞	28⅝	28½

Table X Weight per Yard in Ounces of Finished Cloths

	Ax	A		B		C		D	
	(1) Unbackwashed (2) Continental Combed (3) Continental Drawn	(1) Continental Combed (2) Backwashed (3) Continental Drawn		(1) Backwashed (2) Continental Combed (3) Continental Drawn		(1) Backwashed (2) Noble Combed (3) Cone Drawn		(1) Backwashed (2) Noble Combed (3) Continental Drawn	
	Mule 1	Mule 3	Cap 5	Mule 7	Cap 9	Ring 11	Cap 13	Ring 15	Cap 17
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.
Milled—Finisher A ...	11·25	11	11·06	10·68	11·31	11·56	11·56	11·18	10·81
Clear—Finisher A ...	10·81	10·12	10·31	9·81	10·37	10·68	10·68	10·5	10·68
Clear—Finisher B ...	11·93	11·37	11·5	11·25	11·56	11·93	11·93	11·81	11·62

Average Strength of Grey and the Various Finished Cloths

The cloths were tested at the standard size of 9 inches and 6⅝ inches and between clamps 7 inches apart. The test patterns covered the full width of the cloth, and in the weft direction the samples were selected so as to avoid testing more than one pattern in the same width. As in the case of the yarns, the cloths were exposed for 48 hours to an atmosphere of uniform temperature and humidity to ensure accurate relative results.

Strength of Grey and Finished Cloths

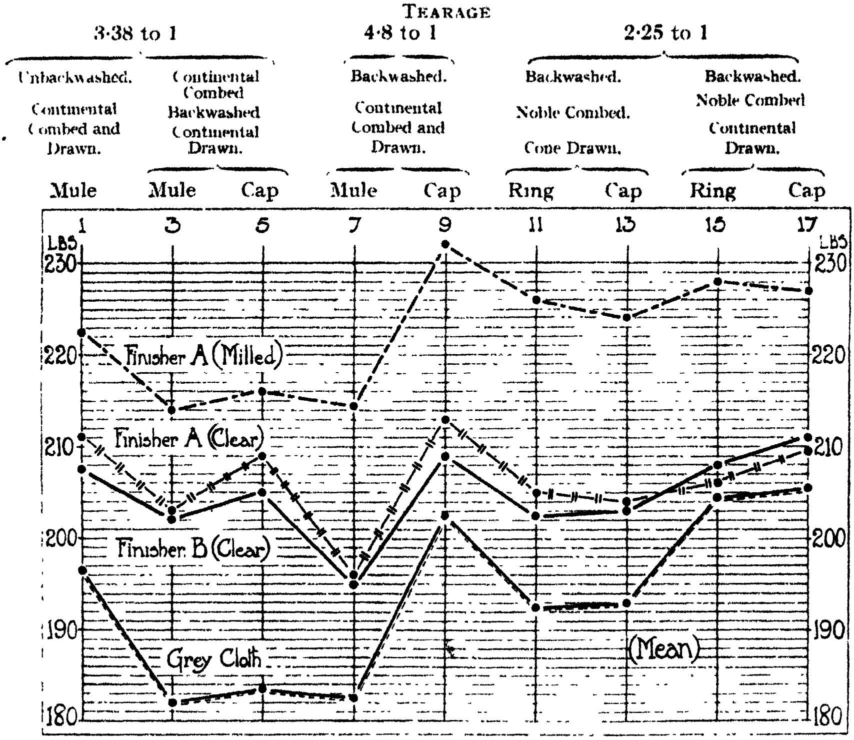


FIG. 8

COMPARISON OF THE VARIOUS DYED AND FINISHED CLOTHS

Summary of the Opinions of Sixteen Cloth Sellers and Buyers

(1) That the whole range of cloth is more "foody" in handle than similar quality of cloth produced from the longer and more typical Bradford wool.

(2) Detailed comparisons of the various cloths—

A—*Comparison of Continental and English Methods of Yarn Manufacture.*

Cloth 7	*Cloth* 13
Backwashed, Continental Combed, Continental Drawn, and Mule Spun.	*Backwashed, Noble Combed, Cone Drawn and Cap Spun.*

(*a*) Milled Finish. Finisher "A"

Rounder Twill. Softer, more velvety. Better and clearer twill.	Firmer handle.

Most Merchantable—No. 7.

(*b*) Clear Finish. Finisher "A"

More level.	Firm handle.
Better handle and twill appearance.	
Smarter.	

Most Merchantable—No. 7.

(*c*) Blue and "Clear" Finisher "B"

Uneven finish.	More level.
Handle—Fuller, softer, and more weighty.	Better finish.
	Smarter.
	Firm handle.

Most Merchantable—No. 13. (The finish given to the blue range particularly suits No. 13. With different and more suitable treatment, No. 7 could be considerably improved.)

B—*Comparison of Mule and Cap Spun Yarns (Continental Combed and Drawn).*

Cloth 7	*Cloth* 9
Backwashed, Continental Combed, Continental Drawn, and Mule Spun.	*Backwashed, Continental Combed, Continental Drawn, and Cap Spun.*

(*a*) Milled Finish. Finisher "A"

Slightly better cover and more level.	Clearer twill.
	Firmer.

Most Merchantable—A matter of opinion. No. 7 for handle, No. 9 for clearer twill.

(*b*) Clear Finish. Finisher "A"

Slightly more even and smarter.	Firmer.
	Slightly less even.

Most Merchantable—Slight preference to No. 7.

(*c*) Blue and "Clear" Finisher "B"

Handles heavier.	Clearer twill.
Burst twill.	Firmer.
Better cloth handle.	

Most Merchantable—No. 7.

C—*Comparison of Ring and Cap Spun Yarns (English Combed and Drawn).*

Cloth 11	*Cloth* 13
Backwashed, Noble Combed, Cone Drawn, and Ring Spun.	*Backwashed, Noble Combed, Cone Drawn, and Cap Spun.*

Finishers "A" and "B"

Uneven	Milled Finish Clear Finish Blue, Clear Finish	Better appearance and handle.

Most Merchantable—No. 13.

D—*Comparison of Yarns, Cone and Continental Drawn, Cap Spun.*

Cloth 13	*Cloth* 17
Backwashed, Noble Combed, Cone Drawn, and Cap Drawn.	*Backwashed, Noble Combed Continental Drawn, and Cap Spun.*
(*a*) Milled Finish.	Finisher "A"
Smarter and firmer.	Softer and fuller.
(*b*) Clear Finish.	Finisher "A"
Smarter and firmer.	Softer and fuller.
(*c*) Blue and "Clear"	Finisher "B"
Smarter. More level twill.	Better handle. More top.

Most Merchantable—A matter of opinion. No. 13 for smartness; No. 17 for handle.

E—*Comparison of Combed Material, Backwashed before and after Combing.*

Cloth 5	*Cloth* 9
Continental Combed, Backwashed, Continental Drawn, and Cap Spun.	*Backwashed, Continental Combed, Continental Drawn, and Cap Spun.*
(*a*) Milled Finish (*b*) Clear Finish (*c*) Blue, "Clear" Finish	Better handle and appearance.

Most Merchantable—No. 9.

(3) *Best Cloth*—

(*a*) In all instances, with one exception, No. 1 unbackwashed material was put forward as the best cloth of the range. The exception being No. 7 or No. 9 for "clear" finish.

(*b*) The following were put forward as the second best—No. 7 for quality, appearance, handle, etc., No. 9 for smart twill and handle, No. 13 for clear twill, appearance, and firm handle.

HOSIERY FABRICS

The hosiery yarns 2/20s (for particulars see Table VII and Fig. 7) numbered—

W	*X*	*Y*	*Z*
Continental Combed	Backwashed	Backwashed	Backwashed
Backwashed	Continental Combed	Noble Combed	Noble Combed
Continental Drawn	Cone Drawn	Cone Drawn	Continental Drawn
Mule Spun	Mule Spun	Cap Spun	Cap Spun

were manufactured by Mr. H. F. Lancashire (J. B. Lewis & Sons Ltd., Nottingham) into vests for underwear, who reports as follows—

"The four different lots were worked on the same machine, one after the other, without any alteration. They worked equally well in the winding and manufacturing processes.

The goods were all given the same milling and finishing processes. The treatment in milling being ordinary, white soap only used and the water kept at a temperature of 130°. Each material had a slight touch of the brush on the inside.

According to our judgment, the vest marked *Y* is perhaps the best, then we should place *Z*, but *X* is so near to *Y* that while the latter would be preferred if the prices were the same, yet if *X* could be produced cheaper than *Y* there is so little between them that we consider *X* would represent the best value."

Table XI Weights and Dimensions of Hosiery Fabrics before and after Finishing

	W	*X*	*Y*	*Z*
As received from Factory—				
Weight in ozs.	12	12½	13	13½
Width in inches	20	19½	19½	19½
Length body in inches ...	32	33	33	33½
Length sleeve in inches ...	12	13	13	13
After Board only—				
Weight in ozs.	11	11½	12	12½
After Conditioning—				
Weight in ozs.	12	12½	13	13½
After Finishing—				
Weight in ozs.	11	11½	12	12½
Width in inches	19	19	18½	18½
Length body in inches ...	29	29½	31½	32½
Length sleeve in inches ..	11¼	11¾	11¾	13

DEDUCTIONS

Raw Material

The characteristics of material composed of short fibre dominates the whole range of cloths, and provides them with a more foody handle than in the case of cloths produced from longer types of similar wool.

Combing

The products of Continental combing give the best results when handle is the primary factor. Further, the fibres of this material are capable of being worked (shrunk and felt) to a much greater extent in cloth finishing than the products of the Noble comb. This is an important factor in the production of face finished dress fabrics such as velours, sedans, amazons, etc. (Particularly have these structures of Continental manufacture excelled those of British production.) On the other hand, the Noble combed material has provided the fabrics of the smartest twill and weave appearance.

Backwashing

The unbackwashed material has provided the best cloth of the range, also the strongest and most elastic of the yarns and cloths.

Drawing

The products of cone drawing are weaker and less elastic than those of Continental drawing. This is a confirmation of a discovery of a previous investigation.

Spinning

A most striking feature is the result obtained from Continental drawn, cap spun material. Apart from the cloth produced from unbackwashed material, these cloths compare most favourably with those manufactured by mule spun yarns. This is a confirmation of a result obtained in a previous investigation and indicates the probability of producing the typical Continental cloth whilst maintaining the cap method of spinning.

Finishing

The uniform treatment given to each batch of cloths obviates the properties contained by individual fabrics being developed to the utmost. For example, in cloths 7 and 13 the treatment of Finisher "B" is most suitable to cloth 13, whereas cloth 7 provides the best result in the hands of Finisher "A". By modified treatment Finisher "B" states that the finish of cloth 7 would be considerably enhanced.

Hosiery Fabrics

The report forwarded in respect to the above indicates that little difference is to be found in the finished products of the various methods of yarn manufacture. Hence it appears that the distinguishing features of the so-termed mule spun Continental yarn is due to the employment of the shorter types of worsted wools.

Received 14/11/33

EXPLANATORY NOTE

"37—A THEORETICAL AND PRACTICAL INVESTIGATION OF THE OPERATION OF THE LOOM"

By Dr. Ing. E. Honegger

Since the appearance of the above paper in our December 1933 issue, the attention of the Author has been drawn to the fact that it is usual in this country to express "kinetic energy" and "flywheel effect" in terms of "mass" and "radius^2" whereas in the calculations in this paper (see page T422) "diameter^2" has been used. The value thus arrived at, divided by $4g$ (g=acceleration due to gravity) gives the "moment of inertia" of the rotor.

This paragraph is published at the author's request to avoid any misunderstanding of his results—*Editor.*

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

5—PSYCHOLOGICAL INVESTIGATIONS OF THE INFLUENCE OF THE VARIOUS METHODS OF MANUFACTURING WORSTED YARNS ON SINGLE AND TWO-FOLD TWIST-WARP CLOTHS—(*a*) CLEAR-FINISHED; (*b*) MILL-FINISHED

By HENRY BINNS, F.T.I.

INTRODUCTION

During the War, an Exhibition of German-made cloths was held under the auspices of the Yorkshire Section of the Textile Institute in the rooms of the Bradford Chamber of Commerce. Two investigations were conducted by an Advisory Committee appointed as an outcome of this Exhibition. It was the aim of the investigations to obtain definite and comparative information regarding the effect of the various methods of manufacturing worsted yarns on the properties of the finished cloth. Two carefully compiled reports[1, 2] have been published and reference is to be made to them for methods and data.

In the first report (p. 120) an "examination of the cloths" and a "summary of the opinions of merchants" is given. In the second report (p. T84) a "comparison of the opinion of the various dyed and finished cloths" and a "summary of the opinions of 16 cloth sellers and buyers" is given. The two reports give full details from which the conclusions arrived at may be checked. But, in the two concluding paragraphs referred to, no evidence of this nature is presented and there is no proof of the statements made.

Interested in the science of psychology, the writer, a business man, conceived the idea of attempting to supply the evidence in the same detail and with the same care as had been exercised in the technical reports. The conclusions now arrived at are the result of pioneer work which may be improved in subsequent experiments. But on principle, it appears to the writer that at all stages in practical commercial life where there is a complete break of control as, for example, during selling and buying, there is as much need for research work on the measurement of personal judgment as there is within the domains of physical measurement. Indeed the measurements by the mind and senses now attempted is but a different method—sometimes more, sometimes less appropriate—of arriving at the same goal.

Professor E. Midgley offered the author every facility for sampling the cloths and together with Mr. J. Dumville, the spinner of the yarns, gave every possible assistance in connection with these investigations.

THE CLOTHS AND METHODS EMPLOYED IN THE INVESTIGATION

The cloths had been made 28 inches wide and samples were cut each 28 inches long. The greatest care was taken that all should be the same in folding, so as to bring the twill and the face of the cloth alike in each case.

Plain tickets and identification numbers were carefully prepared so as to afford no possible clue, and in addition judges were asked to work with the tickets hidden.

The experiments were made in a quiet office, away from the centre of the city, where ample counter accommodation and good light on the second floor was available. Every care was taken to ensure impartial judgment. Though time was recorded, unknown to the judges, no time limit was fixed; each person working at his or her own rates. The following ranges, details of which appear in Table I were presented to each judge, each person having to grade 69 cloths in all.

From the First Inquiry[1]—

For "full" judgment—17 "milled" cloths (R2); and 15 "clear" cloths (R3).

For "partial" judgment (sight only)—10 "milled" cloths (R1).

" " (touch only)—10 "milled" cloths (R1).

From the Second Inquiry[2]—

For "full" judgment—6 "milled" cloths (R4) and 6 "clear" cloths (R5).

For "suggestion" judgment—5 "clear" cloths (R6).

THE SELECTED JUDGES

As no information was available respecting the capabilities of persons invited to judge, the usual trade custom was followed of selecting those having a reputation for impartiality and skill in kindred matters, *i.e.* the type of person invited to arbitrate for the Chamber of Commerce. Of the first 50 persons chosen, experience in their particular branch of the industry averaged 26 years. Five representatives were chosen from each of the following sections—

1—Botany Spinners.
2—Coating Manufacturers (selling grey goods).
3—Coating Manufacturers (selling dyed goods).
4—Dyers of Botany Cloths.
5—Agents for Home and Continental Manufacturers.
6—Wholesale Buyers.
7—Assistant Wholesale Buyers.
8—Commercial Travellers selling to the Retail trade.
9—Buyers for Retail Dress Departments.
10—Lady Buyers for Costumiers.

THE INSTRUCTION TO JUDGES

The subjects were asked to grade the various ranges of cloths—

1—By *sight* alone, for "smartness of appearance" the experimenter placing the cloths in rank order, as desired by the subject.

2—By *touch* alone, for "softness of handle" great care being taken to avoid even a casual glance at the cloths. Blind-folding was found to be unsuitable, being unnatural and likely to disturb the normal judgment.

3—By *full* judgment on a commercial basis of unfettered judgment, the instruction being to "place the cloths in the order in which you would buy them if all were offered at the same price"—any deliberate or subconscious preference might thus be biassed towards smartness of appearance, softness of handle, or other characteristic, according to the fancy of each person.

METHODS OF MEASUREMENT

After testing various methods, the Rank Differences (Co-ordination) as developed by Spearman, appeared to be adequate for the purpose. This method is fully explained in a previous paper[3] published in this *Journal*. To avoid repetition the following are the "probable errors" for the various ranges—R2 and R3 ±·11; R1 (10 samples) ±·14; R4 and R5 ±·18; R6 ±·20.

Table I—Analysis of Cloth Grading
Comparison of Range R2—Milled Finish, with Range R3—Clear Finish

2×2 Twill Cloth made from 60's Typical Bradford.

(*a*) 2/56's Warp (18 × 16 turns).
1/28's Weft (10 turns).

(*b*) 1/28's Warp (15 turns).
1/28's Weft (10 turns).

No.	Combing	Drawing	Spinning	Warps	R2 Milled		R3 Clear	
					Av. place.	Grading	Av. Place	Grading
A	Noble	Cone	Cap	2/56	4·76	100	—	—
B	French	French	Mule	2/56	5·14	95	5·46	74
C	French	Open	Cap	2/56	6·52	79	9·82	16
D	French	French	Cap	2/56	7·00	73	6·30	63
E	French	Cone	Cap	2/56	7·68	65	—	—
F	French	French	Cap	1/28	7·96	62	10·48	7
G1	French	French	Mule	1/28	8·36	57	—	—
G2					10·24	34	—	—
H1	Noble	Cone	Cap	1/28	8·66	53	—	—
H2					11·04	25	—	—
J1	Noble	French	Mule	1/28	8·86	51	6·60	59
J2					—	—	5·92	58
K	Noble	French	Mule	2/56	8·86	51	7·48	47
L1	Noble	French	Cap	1/28	9·00	49	7·40	48
L2					—	—	10·26	10
M1	French	Cone	Cap	1/28	10·92	26	9·34	22
M2					—	—	10·42	8
N	Noble	Cone	Cap	1/28	—	—	7·94	41
O	Noble	Open	Cap	2/56	12·20	11	3·54	100
P	Noble	Open	Cap	1/28	12·72	4	8·04	40
Q	French	Open	Cap	1/28	13·08	0	11·00	0

G1 & 2, H1 & 2, J1 & 2, L1 & 2, M1 & 2 = Duplicate Samples

ANALYSIS OF THE JUDGMENTS OF 50 INDIVIDUALS ON FULL RANGES OF MIXED TWO-FOLD AND SINGLE WARP CLOTHS

From the records of each judge an average "mass" opinion was calculated. By adding the various places in a range recorded against each cloth and dividing by the number of cloths under judgment an average place was secured. From this average the cloths were graded according to the "mass" opinion of the judges, and Table I indicates the respective positions of the various types of cloths (which varied as to combing, drawing, and spinning). Columns 7 and 9 in the table indicate this grading, counting within each range the best cloth as 100 and the worst as 0.

Two-fold and Single-warp Cloths: Preferences in Ranges R2 and R3

Certain analyses of the full judgments will be noted hereunder. First consider the difference between 7 two-fold and 10 single-warp cloths made from the same wool by similar methods of combing, drawing, and spinning. In the "milled" range (R2) these were graded as under—

	Two-fold		Single
	100	...	62
	95	...	57
	79	...	53
	73	...	51
	65	...	49
	51	...	34
	11	...	26
			25
			4
			0
Average ...	68		36

It may be definitely asserted then that, other things being equal, two-fold warps are much preferred (a preference of two to one) to single warps.

In the "clear" range (R3) the gradings were—

	Two-fold		Single
	100	...	59
	74	...	58
	63	...	48
	47	...	41
	16	...	40
			22
			10
			8
			7
			0
Average ...	60		29

Again a two to one preference of two-fold warps.

First Choice of Two-fold Milled and Two-fold Clear Cloths

Such a large range as 17 cloths, presents real difficulty even for highly-skilled judges, but having spent many hours in such investigations, no surprise was felt at the delicate judgments recorded. The minute differences then recognised will probably be more appreciated in the future than now.

The difference in the "milled" cloths between Bradford combination (A), and Continental combination (B) is only 5%, whilst (C) a mixed combination, is 17% lower than (B)—quite an appreciable drop. The fact is that Bradford can supply a slightly better cloth than the Continent on its present machinery. Combination (C) seems entirely unsuitable for "milled" cloths probably owing to the open drawing.

Among the "clear" cloths, combination (O), unsuitable to a milled finish, is specially acceptable with a "clear" finish, in which it is an outstanding first choice at 100, its next competitor, a Continental combination, only recording 74. Cloth C shows a turn-over from 79 milled to 16 clear. These seem to indicate that the vital difference may depend upon finish rather than on combing, drawing, or spinning.

Single-warp Gradings (Milled Cloths)

At the same time that the full range of 17 "milled" cloths was graded two further tests were made by inviting the judges to grade the 10 single warp cloths separately, first by *sight* alone, during which period the investigator handled the samples and, secondly, by *touch* alone, when the judge either closed his eyes or (as some preferred) looked at the ceiling or out of the window. The fact that the experimenter was compelled to assist in the sight and touch tests added to the difficulties of the judges.

It will be seen that these three gradings were made independently, and from different points of view; the *full* judgment having been made when the single warp cloths were mixed with, and screened, by the better two-fold cloths. Table II gives a comparison of the three methods of grading described above. For the comparison which Table II is designed to exhibit, the grading figures assigned to the single warp cloths in Table I were re-calculated, giving cloth F (the best) 100 points and cloth Q (the worst) 0. For easy reference a place order is given as well as the grading.

Table II—Comparison of Single-warp Gradings (Milled Cloths)

No.		*Full* Judgment	*Sight* only	*Touch* only	*Sight and Touch* Average
F	F.F.C.	(1) 100	(4) 100	(2) 100	(2) 100
G_1	F.F.M.	(2) 92	(3) 105	(7) 8	(6) 57
H_1	N.C.C.	(3) 86	(6) 82	(1) 121	(1) 102
J_1	N.F.M.	(4) 82	(1) 122	(6) 31	(4) 77
L_1	N.F.C.	(5) 80	(2) 106	(5) 48	(3) 77
G_2	F.F.M.	(6) 55	(5) 86	(3·5) 56	(5) 71
M_1	F C.C	(7) 42	(8) 46	(9) −13	(8) 16
H_2	N.C.C.	(8) 40	(7) 57	(3·5) 56	(7) 56
P	N.O.C.	(9) 7	(9) 22	(10) −21	(9) 0
Q	F.O C.	(10) 0	(10) 0	(8) 0	(10) 0

The correlation co-efficients of the above gradings are—

Full compared with *Sight* Judgment	+·75
Full ,, *Touch* ,,	+·54
Full ,, the *average* of Sight and Touch Judgments	+·86
Sight compared with *Touch* Judgment	+·27

In spite of the difficulties referred to in judging, there is a correlation of +·86 between a full judgment and the average of sight and touch judgments. Sight and touch compared give only a co-efficient of +·27 showing that cloths are sometimes good to sight and poor to touch and *vice versa*, though the coefficient +·75 shows that sight is the dominant influence in full judgment, touch being only +·54. These figures seem most important both from the points of view of research, commerce, science, and education. Their interpretation and value as a guide for training purposes appears obvious.

First Choice of Single-Warp, Milled Cloths

Open drawing and cap spinning would appear to provide the least desirable cloths for a milled finish. Cloth (F) appears to afford the best combination (100) with G_1, entirely French, second (92), and H_1, entirely Bradford, third (86).

In Table II, French machines are recorded 13 times and Bradford machines 17 times. On this basis the best and worst groups of five cloths to *sight* and *touch* were separated and stated in percentage as follows—

	Sight		*Touch*	
	French	Bradford	French	Bradford
Best Five Cloths	85%	24%	46%	53%
Worst Five Cloths	15%	76%	54%	47%

This seems to show that, on the whole, single-warp cloths made on Continental types of machinery are more "viewly" than the British types. The decision on touch is not so definite though there is a bias in favour of British cloths.

In order to trace the effect of sampling, two lengths from the same cloths, G_1 and G_2 (French combination) and H_1 and H_2 (British combination), had been inserted for comparison. The averages of these are—

	Full	*Sight*	*Touch*	*Sight and Touch* Average
G_1 and G_2	74	95	32	64
H_1 and H_2	63	69	89	79

An experienced pattern room manager knows that samples should be carefully selected, not cut indiscriminately, even from one sample piece. The above variations in grading two apparently identical samples confirm this.

Grading and First Choice of Single-warp, Clear-finished Cloths

By withdrawing the two-fold warps again as in the milled range (see page T92), and denoting the best single-warp cloth as 100 and the worst as 0 the ten "clear" finished cloths are graded as in Table III.

Table III—Single-warp Gradings of "Clear" Finished Cloths

					Average of Duplicates
J_1	N.F.M.	(M)	(2)	87	93
J_2	N F.M.	(C)	(1)	100	
K	N F M.		(4)	69	
L_1	N.F.C.	(M)	(3)	71	43
L_2	N.F.C.	(C)	(8)	15	
M_1	F.C.C.	(M)	(7)	33	22
M_2	F.C.C.	(C)	(9)	11	
N	N.C.C.		(5)	60	
P	N.O.C.		(6)	58	
Q	F.O.C.		(10)	0	

The samples available contained no complete Continental combinations (French combing; French drawing; Mule spinning) but there are two definitely British combination cloths, N and P.

The preference for cloths in Table III made on French or British machines are—

	Full	
	French	British
Best Five Cloths	64%	42%
Worst Five Cloths	36%	58%

This shows a definite bias towards the French systems in single-warp clear finished cloths. In this range the differences are between cloths made mainly on the French or mainly on the British machine types rather than on complete French or British systems.

Three sets of duplicates had been inserted, as in the "milled" range (above). But in order to test the effect of an objective suggestion the letters M (to suggest "Mule") and C (to suggest "Cap") were placed on the cloths. Judges were told that their own opinions must be formed as to the significance of these letters and that no further information could be given. It is difficult to draw any definite conclusion as to the influence of the suggestions given. Cloth J_2 (marked C) is 100 and better than the J_1 (marked M) at 87. These cloths must have been uniformly well-made to be judged so evenly. There was a very definite preference for L_1 (M) at 71, whilst L_2 (C) was only 15—a proportional agreement of only 20%, whereas between M_1 (M) at 33 and M_2 (C) at 11 there is a proportional agreement of 33%.

The experimenter concludes that the judges more or less believed mule spinning was better than cap spinning and perhaps subconsciously duplicates marked M were placed amongst the cloths most preferred.

ANALYSIS OF THE MASS JUDGMENT OF 50 INDIVIDUALS ON TWO-FOLD WARP CLOTHS RESPECTING "FINISH" AND "SUGGESTION"

Having graded two complicated and large ranges of 17 and 15 cloths, three short ranges of six (R4), six (R5) and five (R6) cloths each were next tried.* The 64's Cape Merino used was of nine month's growth and therefore much shorter than that used in the previous inquiry. The same 50 persons graded these cloths immediately after judging the previous ranges. The conditions were the same in ranges R4 and R5, but in R6 *personal suggestion* was employed as follows. The experimenter having placed the cloths in a fixed order stated that the order chosen was considered the best and asked the judges to confirm that order or to rearrange the cloths according to their own preference. Some judges at once mixed the cloths up and re-started by their usual methods. Others looked over and handled the cloths in fold only and changed one or two samples without the close examination given to ranges 4 and 5. A smaller number accepted the suggestion and thought that no change could be made. The analysis of the three judgments is given in Table IV.

Table IV—Grading of Ranges R4, R5, and R6

2 × 2 Twill Cloth made from 64's Cape Merino, nine months' growth.
2/40's Warp (15 × 11 turns).
1/20's Weft (10 turns).

No.	Combing	Drawing	Spinning	R4 Milled (6 cloths)		R5 Clear (6 cloths)		R6 Mid. (5 cloths)	
				Average Place	Grading	Average Place	Grading	Average Place	Grading
R	(B) Noble	Cone	Cap	2·68	100	2·12	100	1·88	100
S	(B) Noble	Cone	Cap	—	—	—	—	3·70	0
T	(B) Noble	Cone	Ring	2·96	82	2·94	66	—	—
U	(B) French	French	Mule	3·32	58	3·00	64	—	—
V	(B) Noble	French	Cap	3·68	35	4·42	6	3·62	4
W	(B) French	French	Cap	4·14	5	3·96	25	3·42	15
X	French	(B) French	Cap	4·22	0	4·55	0	2·38	72

(B) = When Backwashed

It will be noted that in Range 6 the best cloth (R) 100, and the worst (S) 0, are identical and the general opinion (though individuals differ) is in the exact order presented by the experimenter showing that "suggestion" had, in the mass, taken a well-defined course. Stated in correlation coefficients the agreements between the averages of 50 judges on the same six cloths are—

R4 milled and R5 clear	+·94
R5 clear and R6 suggestion ...	+·27
R4 milled and R6 suggestion ...	—·15

The practical interpretation of these figures is that, chance having been eliminated, the agreement between R4-milled and R5-clear-finished ranges appears to be determined solely by the method of yarn construction. When personal suggestion was introduced it affected judgment of the clear-finished cloths and reduced the coefficient from +·94 to +·27. Its effect on the milled finish cloths—in any case much more difficult to judge—was that reversing the coefficient to —·15.

No direct comparison of either yarns or finish was possible between ranges R2 and R3 but in R4 and R5 the yarns and cloths being identical, but with different finishes, a complete comparison can be drawn. It will at once be observed that the grading is practically the same, there being only a reversal of cloths V and W. The correlation coefficient is +·99 with a probable error of ±·18. These results have certainly not been arrived at by chance and the grading of the two ranges is statistically in almost perfect agreement.

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* Cloths chosen from those prepared for the second investigation[8] (p. T70).

The original aim of the investigation was to decide whether the Continental or British systems of yarn preparation were the better. From the evidence presented the experimenter has no doubt that Noble combing, cone drawing, and cap spinning is the best both on milled and clear finishes with Noble combing, cone drawing, and ring spinning a fair second. The Continental system comes third and the mixture of Continental and British systems seems definitely poor and unsatisfactory.

VARIATIONS IN GROUP JUDGMENTS

The technical analysis of the cloths having been dealt with, the variations in the 10 group judgments (p. T90) called for attention. It seems evident that the mass judgment of a number of experienced persons gives a more reliable and delicate grading of cloths, than is possible from individual grading.

The question arises, therefore, as to how the judgment of a group of persons—*e.g.* spinners—having a specific training of a technical character, compares with that of, say, retail buyers who have received a more superficial if more sensory training. Accepting the gradings already made as standards and comparing, by statistical methods, the gradings of each individual in a group and, taking the average of the group of five, a comparison is possible.

Group Ranking

For purposes of group comparison Table V gives the comparison of groups on each range with the standards—

Table V

Groups	*Placings*	R1 Sight 10 Cloths	R1 Touch 10 Cloths	R6 Milled 5 Cloths	R2 Milled 17 Cloths	R3 Clear 15 Cloths	R4 Milled 6 Cloths	R5 Clear 6 Cloths	*Average*
Spinners ...	(8·5)	·27	·22	·19	·39	·40	·46	·39	·41
Mfrs. (Grey)	(2)	·42	·01	·28	·62	·61	·63	·75	·65
Mfrs. (Dyed)	(3)	·49	·16	·39	·51	·70	·39	·78	·60
Dyers ...	(10)	·34	·04	·18	·48	·14	·44	·02	·27
Agents ...	(4·5)	·47	·00	·09	·60	·69	·00	·62	·48
Wholesale Buyers ...	(1)	·59	·30	·24	·57	·66	·71	·68	·66
Assistant Buyers ...	(6)	·39	·07	·18	·59	·38	·40	·31	·42
Wholesale Salesmen	(7)	·38	·12	·28	·58	·32	·51	·38	·45
Retail Buyers ...	(8·5)	·75	—·45	—·11	·58	·57	—·14	·55	·39
Lady Costumiers	(4·5)	·46	·09	—·40	·41	·44	·36	·61	·46
Average	...	·46	·15	·14	·53	·49	·37	·51	·47

The final ranking of groups (column 2) was determined on the basis of the average scores on ranges R2, R3, R4, R5 in which there were full and impartial judgments and no personal suggestion employed.

In the "sight" grading (R1) as might be anticipated, retail and wholesale buyers rank first and second and spinners, whose acquaintance with their yarns in the piece is limited, were the poorest judges.

By "touch" grading (R1) the retail and wholesale buyers retained their respective positions; agents and grey manufacturers occupying the lowest places. It will be noted that "sight" judgment maintained its superiority over "touch" judgment.

In grading range (R6), introducing personal suggestion, resistance was greatest by manufacturers of dyed cloths whilst lady costumiers yielded to the suggestion almost completely.

Range R2 does not require comment, but on range R3 manufacturers (dyed goods), agents, and wholesale buyers, a trio working together in business agreed well with the mass judgment. The clear finish was fashionable at that time and thus appealed to these groups. Dyers were at the end of these placings.

In range R4 wholesale buyers came first and manufacturers (grey goods) second, whilst agents disliked this milled range as did retail buyers.

Range R5, most attractive cloths, showed high coefficients with manufacturers (dyed goods) first at +·78 and dyers lowest.

Group Characteristics

From Table V it would appear that those sections having most financial responsibility, nearest the completed article, or having technical knowledge of the cloth structure as a whole, give the best judgments. Those, on the contrary, who deal with only a section, such as spinners and dyers, do not judge the whole but mainly the particular differences to which training has given a bias. Between the two are those with little financial responsibility, or no pronounced technical knowledge, but biassed by the more general but superficial aspects of the grading, *e.g.* agents, lady costumiers, assistant wholesale buyers, wholesale salesmen, and retail buyers.

In the main when the cloths are from the same wool, the most decisive group decisions are arrived at on clear finished cloths with a bias on appearance, and when personal and objective suggestion is absent. These points should be borne in mind as the beginning of technical instruction. As progress is made, milled cloths, the sense of touch, and the introduction of a difficult environment are essential to higher spheres of judgment.

If the judges are arranged individually according to their average scores in the full judgments on ranges R2, R3, R4, and R5, and ignoring the partial judgments, then the number of persons coming within the groups and occupying the places may be stated as in Table VI.

Table VI

	Places				
	1–10	*11–20*	*21–30*	*31–40*	*41–50*
Spinners	1	1	—	1	2
Manufacturers (Grey Cloths) ...	3	1	1	—	—
Manufacturers (Dyed Cloths) ...	2	1	—	2	—
Dyers	1	—	—	2	2
Agents	—	2	1	1	1
Wholesale Buyers	3	1	1	—	—
Assistant Buyers	—	2	—	1	2
Wholesale Salesmen	—	—	3	1	1
Retail Buyers	—	1	1	2	1
Lady Costumiers	—	1	3	—	1

The spinner and dyer coming within the first 10 places were in control of cloth manufacture and in consequence may be assumed to have preferential knowledge, though it is open to doubt as to what extent this would be a real help in the personal judgment they actually made of the cloths. Omitting these, the best judges are wholesale buyers and manufacturers. It must not be assumed that those in the lower places are poor judges but rather that on tests of extraordinary difficulty, which not one of them had ever tried before, it is possible to state in figures a measurable difference. The significance of this from the educational standpoint must be appreciated as it opens up a fairly accurate method of analysing personal judgment of textiles in its most delicate operations.

INTER-AGREEMENT BETWEEN GROUP JUDGMENTS

The productive side of the worsted industry of the West Riding is divided into wool merchants, topmakers, spinners, manufacturers, and dyers, whilst the distributive side is covered mainly by agents, merchants, costumiers, and retailers. It is generally admitted that all sections are interdependent and yet the specialisation within the limits of each is so intensive that little attention is given to the connection between them. This inter-relationship of judgment is now attempted. The average agreement between each section and the other nine sections is summarised in Table VII.

Table VII—Inter-agreements between Groups

				Full Judgment				
	R1 *Sight*	R1 *Touch*	R6 *Suggestion*	R2 *Milled*	R3 *Clear*	R4 *Milled*	R5 *Clear*	Average of R2, R3, R4, and R5 *Full Judgm't*
Spinners ...	·49	—·03	·59	·48	·65	·32	·65	·52
Manufacturers (Grey Cloths)	·46	—·10	·74	·68	·60	·46	·72	·61
Manufacturers (Dyed Cloths)	·63	·05	·54	·53	·63	·28	·81	·56
Dyers	·49	—·03	·58	·63	·29	·34	·39	·41
Agents... ...	·48	·19	·52	·61	·66	—·06	·80	·50
Wholesale Buyers ...	·39	·27	·58	·69	·65	·41	·77	·63
Assistant Buyers ...	·63	·14	·75	·64	·64	·46	·71	·61
Wholesale Salesmen ...	·57	·02	·74	·74	·45	·46	·55	·55
Retail Buyers	·69	—·04	·57	·71	·65	—·72	·62	·26
Lady Costumiers ...	·61	·14	·31	·67	·58	·42	·77	·61
Average ...	·54	·06	·59	·64	·58	·24	·68	·53

The average of the full judgment means, in effect, the agreement between one group of five persons each grading 44 cloths (a total of 220 placings) compared with nine groups of five persons also grading 44 cloths each (a total of 1980 placings). In these terms it seems remarkable that the result shows a positive correlation of +·53.

Generally speaking, it may be said that the opinion of any one group is in accord with the opinion of any other groups on these tests. As the subjects ranged from highly-trained technical men to empirically-trained individuals it would appear to indicate that concentrated experience may have results in respect of judgment analogous to those of technical training.

DISCRIMINATION OF DIFFERENCES

After trying numerous methods for assessing the ability of the judges the final standards were based on the average gradings of 50 persons on cloth ranges R2, R3, R4, and R5 in full judgment.

It would be quite impossible in business life to secure the judgments of so many people, and a workable method of finding the relationship of one cloth to another or one person to another is desirable. This will be dealt with later. Here, possibilities in this direction may be mentioned such as those which would arise out of the questions.

If two-fold and single-warp cloths are mixed, does the sorting into the two groups afford any indication of a judge's ability ?

In this case, ranking in trade groups, the agreement with the accepted standard on milled finishes is +·75 and on clear finishes +·81. This clearly suggests the usefulness of training students in the discrimination of differences of this kind.

If a certain cloth is known, either by knowledge of its production or by sale, to be the best of a range, is the selection of this cloth any indication of ability to grade the full range ?

In practice only the one or two best cloths are required. The relationship between trade groups choosing the best cloth in each range (as determined by the standard) is milled finish +·88, clear finish +·75, showing that the question may be answered in the affirmative.

The duplicate samples in R2 and R3 ranges were inserted in order to test the possibility of measuring the distance between each sample. As already pointed out, samples cut from the same piece varied. What was thought to be a means of detecting the power of observation was not, therefore, really of use as shown by the fact that these measurements only yielded a correlation of +·23 with the final ranking of the 50 individuals. Under different conditions and different materials it seems probable that more effective use might be made of this principle. In this inquiry these figures are entirely omitted.

THE TIME FACTOR

Hitherto the inquiry has been devoted to accuracy and the determination of quality. This is inseparably tied up with the time factor. A scientist or technical expert can in a large measure determine the whole environment in which his work is to be carried out, so that it is neither hurried nor placed under conditions over which he has no control. The business man, on the the contrary, is always called upon to adjust himself to the circumstances of the moment and is not able in consequence to pre-determine conditions. He, therefore, develops the habit of meeting difficulties as they arise and acting on the judgment of the moment. Many now look upon first impressions as the best and are prepared to stake large sums of money on quick decisions. Others are temperamentally slower and wish to put to the test every available factor under consideration. Probably the mass of business men adopt a mean between the two methods.

In the experiments now under review, time was taken by a stop-watch, but it was understood that time was only regarded as of small importance. The 50 persons were ranked first according to accuracy of judgment and secondly as to speed of action. These two series show a correlation —·40 showing that accuracy is associated with a medium to slow judgment. Taken in detail and placing the various ranges in order of association with speed of action, the following are the results—

Quickness with	R1, touch	+·14	(10 cloths)
,, ,,	R6, suggestion	+·04	(5 ,,)
,, ,,	R1, sight	—·04	(10 ,,)
,, ,,	R3, clear	—·09	(15 ,,)
,, ,,	R4, milled	—·17	(6 ,,)
,, ,,	R2, milled	—·23	(17 ,,)
,, ,,	R5, clear	—·54	(6 ,,)

On a full judgment the number of cloths in a range (when time is calculated per unit of cloths), does not require more time, *e.g.*—

R2 and R3 (average 16 cloths)	—·16
R4 and R5 (average 6 cloths)	—·36

The differences between "clear" and "milled" finished are—

R3 and R5 Clear (10·5 cloths)	—·31
R2 and R4 Milled (11·5 cloths)	—·20

The time differences seem to be determined by the definition between the best and the worst cloths in a range and the relative variation in the intermediate cloths. R3 (—·09) had the most definition of the two "clear" finished ranges, whilst in R5 (—·54) the minute variations required more time to detect.

A comparison of the quickest and the slowest judges in each group will give a more individual interest in the relationship between accuracy and time.

Table VIII

	Quickest		Slowest	
	Accuracy	*Time in Secs.*	*Accuracy*	*Time in Secs*
Spinners	·32	10	·70	93
Manufacturers (Grey) ...	·70	31	·71	63
Manufacturers (Dyed) ...	·47	34	·40	96
Dyers	—·19	13	·16	39
Agents	·48	20	·65	52
Wholesale Buyers	·70	20	·71	73
Assistant Buyers	·65	15	·63	60
Wholesale Salesmen ...	·29	12	·33	61
Retail Buyers	·67	20	·46	38
Lady Costumiers	·61	20	·51	46
Average	·47	19	·53	62

Average accuracy for 50 judges	+·46
Average time for 50 judges	38 seconds

The accuracy of the quick and slow groups is nearly equal at +·81, but there is a difference of three to one in time. In the quick group it will be noted that the more rapid the judgment the less the accuracy; a coefficient of —·50. In the slow group this does not occur but the accuracy and time are moderately together at +·32. Ten of the most accurate judges average ·72 accuracy in 53 seconds time, confirming the opinion already stated that on the whole a point midway between medium and slow yielded, in these experiments, the best results.

TEMPERAMENTAL TIME

Individual judges appear to have a temperamental time which shows, when reduced to units of judgment, a fairly uniform rate of speed. Five persons' time in seconds per cloth judged is shown in Table IX.

Table IX

Judge	R1 *Sight*	R1 *Touch*	R6 *Suggestion*	R2 (17 cloths)	R3 (15 cloths)	R4 (6 cloths)	R5 (6 cloths)	*Average*
Y1	12	3	18	5	23	5	7	10
S4	15	12	6	10	12	20	15	13
D2	12	30	12	12	12	10	8	14
S5	24	36	70	55	92	80	80	62
MG3	36	30	84	78	80	80	80	67
MD4	50	42	132	129	84	100	100	91

Y1, a spinner, was so disturbed by the unevenness in the yarn of R3 range that his rate was quite upset. These types fairly represent the uniformity of speed in judging.

Within groups there are individuals of slow and of quick judgment, but it is significant that taking the average time of the five members of each group, there is a singular uniformity. These groups are given in seconds in the next Table.

Table X—Average of Five Persons in each Group of Seven Ranges

	R1 *Sight*	R1 *Touch*	R6 *Suggestion*	R2 17 cloths	R3 15 cloths	R4 6 cloths	R5 6 cloths
Spinners	34	29	46	65	73	44	51
Manufacturers (Grey)	31	37	69	53	52	67	67
Manufacturers (Dyed) ...	41	37	32	57	83	22	29
Dyers	23	32	51	33	31	70	53
Agents	24	38	29	30	31	42	30
Buyers	29	29	40	29	46	41	56
Assistant Buyers	16	26	34	24	31	25	19
Salesmen... ...	21	25	31	27	39	35	33
Retail Buyers ...	18	15	31	28	36	28	32
Lady Costumiers	30	23	38	30	39	39	39
Average (Seconds)	26	29	40	37	46	41	41

It has been shown (p. T98) that in the main the average accuracy of one group compares favourably with the accuracy of another. Comparing time on the same basis and accepting "slowness" as the basis, then the following correlations are shown—

Slowness with	R1, sight	+·37
„ „	R1, touch	+·32
„ „	R6, suggestion	+·54
„ „	R2, milled	+·18
„ „	R3, clear	+·13
„ „	R4, milled	−·09
„ „	R5, clear	−·00

The greater the number of cloths to be dealt with, the greater the need for care, but the different finishes do not materially alter the judgment of those dealing with the completed cloth, though they do so in the case of specialists in one part of the cloth only, *e.g.* spinners, dyers.

OBSERVATIONS MADE BY JUDGES

During the experiments the judges were encouraged to make any observations which might be helpful. These were given spontaneously and shorthand notes were taken by the experimenter who did not converse or join in any discussion. Quietness was considered desirable throughout. The following brief summary of the comments made will indicate the nature of these observations.

General

The distributors, and particularly retailers, said that British productions had been improved as compared with the pre-war period. Bradford cloths were said to handle well and had "guts"; French cloths lacked scale weight, but had a fullness provided by "pneumatic yarns"; German cloths had a "woodenness" about them which was not pleasing.

Methods of Judging

Whilst there was no uniformity of procedure in judging it would appear that a rough selection was first made by sight, followed by a more careful examination by as complete a judgment as possible. The last and final discrimination was almost invariably determined by the sense of touch.

The Appearance of Cloths

Comments made on the appearance of cloths during the tests proved conclusively the wide field of ideas dominating the judgment. These might be summarised in the main by the cloths being "smart, level, clear, well-covered, even, smooth, bright, homogeneous, compact, well-rounded, balanced, 'rawky', rough, irregular, streaky, 'grins', knoppy, crêpy, rubbed-up, clumsy, cockly, thin, flannelly, solid, sharp, stripey, evenly-balanced, and lustrous".

The Handle of Cloths

The handle was said to be "silky, soft, full, kind, firm, pliable, tight, solid, well-bedded, mellow, velvety, rich, elastic, sticky, loose, full, springy, lofty, boardy, weighty, foody, warm, papery, drapes well, cottony, lumpy, dead, and leathery". Speed of action in touch was favoured and many commented on their final decision being based on the sense of touch.

Colour

There was no evidence taken nor was it possible to give any reliable judgment on the colour of the cloths; each cloth within a range being of the same shade.

Comments on "Suggestion"

The best judges resisted a personal suggestion made to them by deliberately mixing the cloths up and keeping the tickets turned down, at the same time stating that they did not wish to be influenced. Others more or less accepted the suggestion and failed to examine the cloths in the manner previously done. *There can be little doubt that had personal suggestion been applied in all the ranges no value whatever could be attached to the present findings.* Comments under this heading showed the need for care in research work, and also the possibilities of the judicious use of this power by commercial travellers.

SUPPLEMENTARY EXPERIMENTS

It is usually found helpful to have the judgments of non-technical and totally-untrained persons in inquiries of this kind. In this instance the services of five individuals were secured and a brief survey of the results achieved is given below.

The Opinions of Two Born-blind Ladies

It was not possible to get them to work separately, and both handled each sample together and seemed to have quite decided opinions uniformly.

Both expressed themselves afterwards as being "very nervous". Compared with the 50 experts their judgments were— .

On R1 touch .	−·04
R2 milled .	+·64
R3 clear .	−·88
R4 milled .	+·53
R5 clear .	−·65
R6 navy .	−1·00

It is interesting to note that on the "milled" ranges they are in agreement with the 50 experts at +·58 but strangely in disagreement on the clear finishes at −·76. This seems to be due to the blind showing preference for material, regardless of finish. The experts on the other hand change their opinions with the finish. Compared with the touch (range R1) of the 50 experts, there is neither agreement nor disagreement at −·04. Again in R2 (milled) all the seven two-fold warps were placed before the remaining 10 single-warps. Sound judgments were formed through the sense of touch only by these blind ladies.

The Opinion of a Lady-fitter with Delicate Touch

In this case there was an all-round average agreement with the standards set up. In the R2 range, however, this lady selected, just like the blind ladies, the seven two-fold warps before the 10 singles. This was mentioned to several of the technical judges who all believed it impossible to distinguish such differences. A fortnight later at the same time of day (10 a.m.) and without any warning, this lady was invited to make a second grading. The seven two-folds were again all placed before the single warps without her being aware of or even knowing the existence of the technical differences. The relationship between this lady's two trials on a 17 cloth range was very high at +·87.

The Opinion of a Kindergarten Teacher

This young lady had the Froebel certificate. She had done excellently in handwork and was considered original and constructive in her ideas. Under several tests she showed outstanding ability. On commencing the tests she neither saw nor felt any difference between cloths and declared it impossible to grade the samples. Compared with the standards she scored—

	Teacher	*Average of Experts*
R1 sight	+·46	+·46
R1 touch	+·62	+·15
R2 milled	−·52	+·53
R3 clear	+·13	+·37
R4 milled	+·73	+·49
R5 clear	+·00	+·51
R6 suggestion ...	+·46	+·14

These figures suggest lack of balance in judgment; yet it is curious that whilst sight is normal and suggestion has had definite influence, the sense of touch is four times stronger than normal. Range R4 was a most difficult task—many felt it to be the hardest—and yet her results are unusual, only four experts doing better. These same characteristics are at the base of the differences on the remaining ranges.

The Opinion of a Skilled Lady-fitter Failing in Health

Cases of failing health have given exceptional results in other inquiries. This lady had had a serious eye operation two years previously. To sight, all cloths seemed alike, but she had little or no hesitation in deciding on touch, using the finger end and thumb in selecting. Two-fold warps were not, as usual, in preference, but were distributed over the ranges. The agreements with the standards are—

R1 sight	+·18
R1 touch	−·15
R2 milled	−·03
R3 clear	+·25
R4 milled	+·53
R5 clear	+·53
R6 suggestion	+·75

An untrained person would not be likely to score so well on R4 and R5 even in perfect health.

CONTRASTS IN INDIVIDUAL SKILL

By accepting the standard grading on four cloths, R2, R3, R4, and R5 by full judgment and excluding the tests for health, touch, and suggestion, it is possible to rank the judges in order of relative merit. From this ranking, the distribution of ability in the various sections is possible. The variations between the first and last five individuals in the ranking on full judgment are as follows—

Table XII—First Five

	No.	R1S *Sight*	R1T *Touch*	R6 *Suggestion*	*Full Judgment* R2	R3	R4	R5	*Average*
1 Mfr. (Grey) ...	MG5	−·28	−·38	·00	·69	·88	·65	·88	·77
2 Mfr. (Dyed) ...	MD1	·84	·37	·46	·67	·53	·81	·88	·75
3 Mfr. (Dyed) ...	MD2	·81	·37	·75	·67	·53	·76	·99	·74
4 Wholesale Buyer	B4	·66	·18	·46	·75	·88	·49	·73	·71
5 Mfr. (Grey) ...	MG3	·37	·26	·46	·71	·73	·41	·99	·71
Average of Tests ...		·48	·06	·43	·70	·71	·62	·89	·73
Last Five									
50 Dyer	D2	·50	·23	·46	·00	·29	−·42	−·65	−·19
49 Retailer... ..	R1	·88	·37	−1·00	·03	−·65	·29	·29	−·01
48 Lady Costumier	L3	·18	−·15	− ·48	·00	−·65	·37	·53	·06
47 Spinner ..	Y2	−·20	·07	·46	·41	·00	·37	−·26	·13
46 Dyer	D1	−·15	−·04	·00	·41	·00	·49	−·26	·16
Average of Tests ..		·24	·10	·11	·17	−·20	·22	−·07	−·03

It should be remembered in examining these figures that each range was graded entirely independently of the others. The first group were all producers of the actual type of cloth under consideration or who buy it in the form in which it was presented. All are highly skilled technical, as well as practical, men. All are holding positions of importance in the trade.

The second group, whilst being first-class people, cannot be said to have the all-round technical knowledge of the first group. Nor can it be said that there is a bias to the purely superficial sensory discrimination. The difference would appear to be that their experience and training has not given them quite the fineness of mental discrimination necessary in order to interpret minute variations through the senses of sight and touch.

THE AGREEMENT BETWEEN PERSONAL JUDGMENT AND COMMERCIAL ABILITIES

It is customary in experiments of this type to compare the results of the tests with opinions from independent sources, *e.g.* the ranking by test of a group of children is compared with the teacher's classification. The more simple the operation, the comparative results should be easier to determine and more reliable. It is notoriously difficult to make comparisons into which a great many complex factors enter. The attempt to rank such a group as the 50 experts engaged in this investigation, serves a useful purpose in realising this complexity, but at the same time of emphasising the importance of other factors than those which have been under consideration.

One principle of ranking is based upon responsibility, either for buildings, plant, buying, or selling, *e.g.* a practical spinner having responsibility for the running of a large plant would rank higher than a salesman for a wholesale distributing house, who would again precede a retail buyer, followed by a lady-fitter with no financial responsibility.

Another principle suggested is that based on the assumption that each person is commencing business on his own account, and a bank manager would assess the credit represented by overdraft to each. Obviously sound personal judgment at once becomes a vital matter—trust cannot be reposed on an erratic judgment. Many important factors would enter more or less into the bank manager's mind. A person of technical training, long experience as a manager, and having the commercial instinct, would obviously rank higher than one with greater and more abstruse theoretical ability but no commercial training.

With a fair knowledge of the duties of each of the 50 persons the experimenter has attempted comparisons by ranking on the three principles with the following result—

		P.E.
Personal judgment by tests, and "Responsibility"	+·43	±·06
,, ,, test, and "Bank Manager"	+·53	±·06
,, "Responsibility" and "Bank Manager"	+·55	±·06

The "probable error" is well covered, showing that chance has been eliminated. The opinion of the experimenter is, of course, open to doubt, and is given as the best obtainable. The results show that a sound personal judgment is fairly well associated with large responsibility and both (as happens in practice) would represent the views of a bank manager with some degree of accuracy.

It is well, however, to point out that the connection is by no means absolute and it is just that difference which is represented between the purely technical man and the practical man with a technical training. The inference is that Technical Education should, as far as possible, develop all those qualities which are fundamental to the well-being of the trade.

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6—A PHOTOMETER OF SPECIAL APPLICATION TO ROUTINE TEXTILE MEASUREMENTS

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The exact measurement of light values is a physical operation of which it cannot be said that complete success has yet been achieved. Notwithstanding the great advances which have been made, particularly in the measurement of the light emitted by primary light sources, the precise evaluation of reflected light and of diffusely reflected light especially, often present difficulties which have so far only been partially overcome.

This is, of course, largely due to the colour differences which exist everywhere even when they are not apparent to the untrained eye, and which make it impossible, for example, to express the reflecting value of a plane surface merely as a simple ratio. The full expression of this reflecting value is a function of the wavelength and is best expressed graphically as a curve which may be integrated in any desired manner to suit the circumstances.

When, in addition, the reflecting surface has a definite surface structure, as for example a woven fabric, the complete graphical statement of its reflecting power will consist, not of a single curve in two dimensions, but of a surface in three dimensions, or possibly something of even higher order.

It is clear, then, that to attain success in such measurements we must simplify them by separating the different variables involved so that the effect of each may be independently assessed and that measurements may later be undertaken with most of the conditions suitably standardised.

The assessment of colour values of fabrics is, of course, ultimately connected with the perception of these surfaces by the human eye, for the principal, if not the only object, in varying the surface reflecting power of fabrics is to satisfy our æsthetic senses through our powers of vision. For most purposes, therefore (though not for all), fabric colour measurements must take due account of the variations which occur in the sensitivity of the human eye.

The measurement of the "colour" of a surface is usually performed in practice by one of two methods. Each of these is, however, in essence, the measurement of the light reflected from the surface under particular conditions.

The first method is by visual comparison, in which the surface is "matched" against another surface of known value. Here the human eye is usually employed as the detector of equality, either directly or with the assistance of various devices, intended to amplify contrast and to assist in eliminating fatigue.

In the second method direct comparison is avoided by measuring the emergent light by means of a suitable direct reading instrument.

This second method lends itself to precise measurements under research conditions, but owing to the delicacy of the instruments and the complication attending their use, it cannot be regarded as generally suitable for industrial purposes.

In the Toussaint photo-colorimeter, for example (*Text. Rec.*, 1927, **45**, 61), a single photo-cell of the vacuum-alkali metal type is employed in conjunction with a powerful mains-derived light source and a delicate galvanometer for measuring light values by either transmitted or reflected light. This instrument, even though capable of giving excellent results under ideal conditions, proves difficult, if not impossible, in industrial use. Direct reading photometers utilising photo-cells and robust galvanometers calibrated in terms of light values have quite recently been available for the measurement of direct light, but, generally speaking, they are not sufficiently sensitive for the measurement of light reflected from matt surfaces.

An interesting but complicated instrument which gives a direct record of the colour analysis of a surface was described by A. Hardy (*Journal of the Optical Society of America*, Vol. 18, p. 96, 1929). A rotating disc shutter is arranged so that light beams reflected diffusely from a standard white surface and from the sample respectively are applied alternately to the same photo-cell, a prism and slit being interposed so that the photo-cell receives only monochromatic light. The alternating currents produced when the system is unbalanced are amplified and caused to move a shutter in the standard light beam so that the system balances itself automatically. A further attachment makes the whole instrument self-recording. More recently a very similar instrument, differing only in matters of detail, has been patented by the General Electric Co. of America (U.S.P. 1,894,132).

Both these instruments are no doubt very satisfactory, but they employ highly complicated optical systems and recording arrangements which make them of necessity very expensive. Moreover, these instruments are not very suitable nor are they easily adapted for routine use in cases where a complete colour analysis is unnecessary and it is sufficient to obtain a single number indicative of the overall departure from pure white. This type of measurement is required in connection with much of the work in the B. L. R. A. laboratories, and it was therefore decided to produce, if possible, an instrument more nearly fulfilling these requirements.

The methods previously in use in the B. L. R. A. laboratories for this type of work have been—

(*a*) The "disc" method. Here a series of discs of tinted plaster of Paris of known composition were arranged to form a number of series ranging from "pure white" to varying shades of blue, yellow, grey, and mixtures of these. By means of these discs any sample of so-called "white" fabric could be roughly matched under approximately standard conditions.

This method is rapid and simple but quite empiric and subject to considerable personal error even if used under conditions as nearly standard as possible by a careful, trained operator. Nevertheless, it is an excellent "field" method for rough work.

(*b*) The "cube" photometer (Adderley and Pelton, *J.T.I.*, 1929, **20**, T203). This method is capable of giving precise results but has the grave disadvantage of requiring a large area of the surface under examination. Moreover, as the readings of the "cube" photometer depend on the sum-total of light reflected from the test surface in all directions, and as many, if not most fabrics, have a different colour value for every different direction of incident and reflected light, it is not at all certain that any results of the cube-photometer will be comparable with the visual sensation of the same surface, which is usually a single sensation for a particular angle of incidence and reflection and is never an average for all possible values.

These two disadvantages in themselves made it desirable to explore other possibilities. As a result the photometer described in this paper has been evolved. In this instrument the object has been to measure the diffusely reflected light under conditions much more comparable with those of direct vision than are possible in the cube photometer. At the same time it was desired to produce a robust instrument, rapid in use, independent or very nearly so of personal error, with a high order of accuracy and consistency and well suited to routine measurements by relatively unskilled operators. Moreover, it should need only a small area of fabric, which need not be detached from the rest of the article of which it is a part.

The achievement of these aims would produce an instrument which would greatly facilitate a system for the testing of Laundry processes by means of "test-pieces" of fabric treated so as to make them colour-sensitive to specific factors such as temperature, bleach concentration, mechanical attrition, etc. It would also enable large-scale washing tests to be conducted on a statistical basis.

It is claimed that these objects have been completely fulfilled by the instrument described below.

The requirements of the test fabric measurements are most conveniently met by a small test area, as it is often inconvenient or impossible to provide a large one. At the same time an unduly small test area introduces other difficulties and may greatly increase the labour involved in obtaining average values for a surface with a pattern or with irregularities of colour or texture.

In order to avoid effects due to regular reflection it was decided to employ angles of incidence and diffuse reflection differing considerably from one another. To obtain a reasonably high light efficiency these angles must be fairly small. From these and other (mechanical) considerations it was decided to make the angle of incidence about 45° with approximately normal reflection.

The relatively small intensity of light reflected from fabric surfaces, even bright ones, made it undesirable to attempt a direct measure of the quantity of reflected light. Direct measurement also introduces the difficulty of maintaining the light source constant. Instead it was decided to compare it with the light reflected from a standard surface under equal conditions, obtaining a balance by reducing, in a known ratio, the light reflected from the standard surface. It would also be better to work the whole as a "null" method if possible, as this is usually more convenient and often more accurate.

The necessity for high accuracy and the avoidance of personal error made it desirable to use an artificial "eye" as the light detector. At the same time it was important that any such device (bolometer, radiometer, photo-cell, etc.), should have spectral response characteristics similar to those of the human eye if its readings (which would be the sum of the individual responses for the different wavelengths) were to be comparable as far as possible with the corresponding sensations of the human eye. In particular it was essential that the detector should not respond to radiation beyond the visible spectrum limits.

This condition, fortunately, is fulfilled remarkably well by the photo-cell finally chosen. This is a new type made by the Westinghouse Brake and Saxby Signal Co., but not yet placed on the open market. Known as the "green" cell, owing to its possessing a peak response in the green region of the spectrum, it consists essentially of a disc of a particular modification of cuprous oxide with metallically conducting surface layers arranged to act as electrodes. The whole is mounted behind a thin glass window in a moulded case, forming a robust and convenient unit. When light is incident on the sensitive surface a small P.D. is produced, which owing to the relatively low impedance can give rise to a comparatively large short-circuit current. The relation between the amount of incident light and the output P.D. for light of constant quality has also been investigated by the N.P.L., who report that provided the light intensity is insufficient to cause a considerable change of temperature there is strict proportionality. This condition is fulfilled in the instrument described in this paper.

An average cell has an internal resistance of the order of 170 ohms for a sensitive surface of 1 in. diameter and gives a short-circuit current at the peak of the response curve of about 70 milliamperes per watt of incident light.

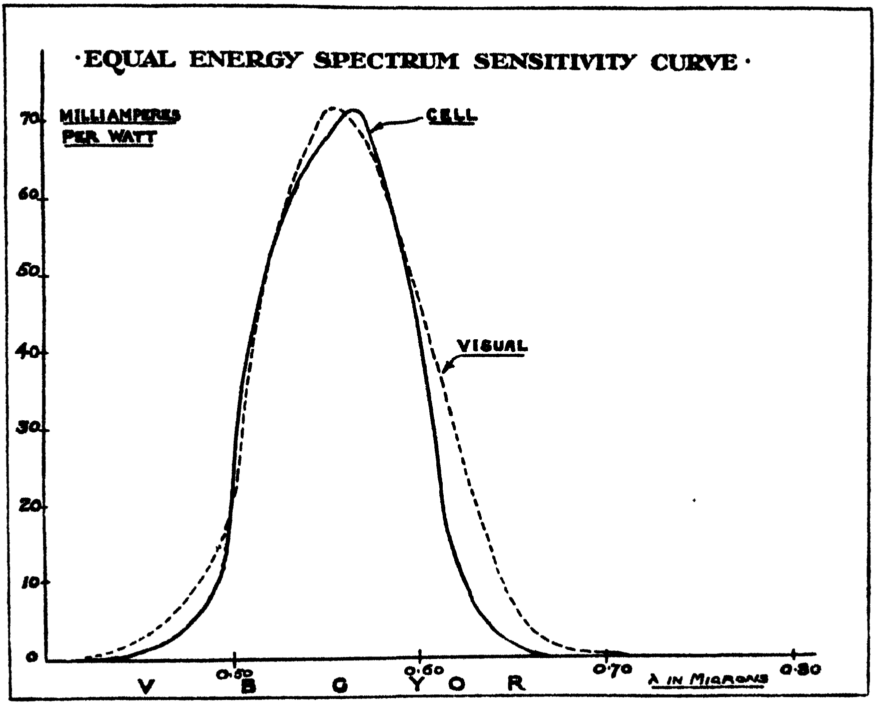


FIG. 1

The response curve of an average cell is given in Fig. 1, which includes for comparison the curve for the human eye. These curves are based on measurements made at the N.P.L. The close agreement of the Westinghouse "green" cell response curve with that for the human eye will be apparent. This cell actually approaches closer to the human eye than any other cell for which data are available. The cell used by Hardy, for example, while having its peak at the right point, gives too much response both at the violet and the red ends of the visible spectrum. An important advantage which emerges from the N.P.L. test is that different cells, while they may vary

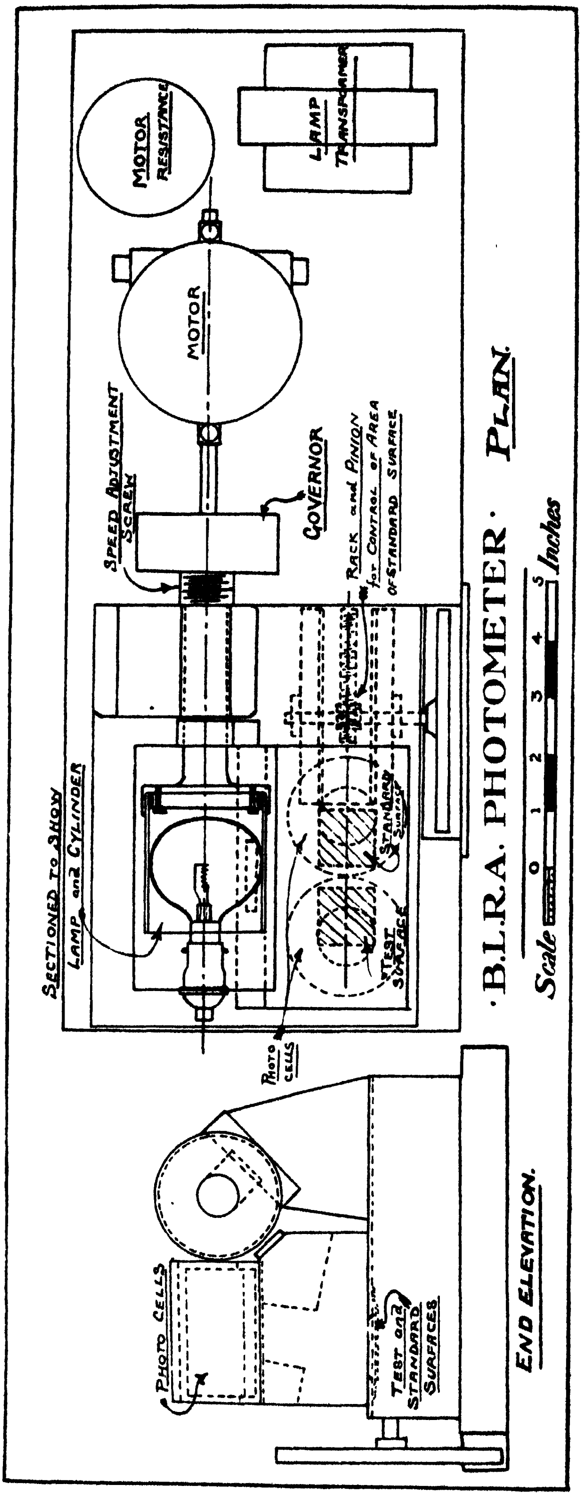
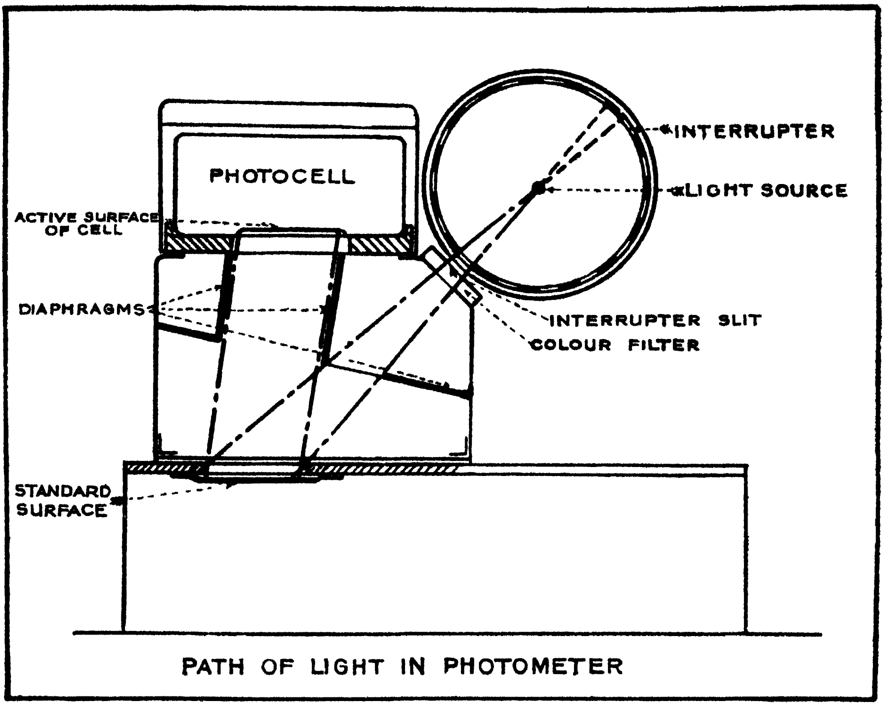

MOTOR RESISTANCE
LAMP TRANSFORMER
MOTOR
SPEED ADJUSTMENT SCREW
GOVERNOR
RACK and PINION for CONTROL of AREA of STANDARD SURFACE
SECTIONED TO SHOW LAMP and CYLINDER
STANDARD SURFACE
TEST SURFACE
PHOTO CELLS
·B.L.R.A. PHOTOMETER· PLAN.
Scale 0 1 2 3 4 5 Inches
END ELEVATION.
PHOTO CELLS
TEST and STANDARD SURFACES

FIG. 3

somewhat in general sensitivity are practically identical in shape of response curve.

The output current of these cells when receiving reflected light from an average fabric surface is rather too small for satisfactory direct reading with any type of galvanometer which would be sufficiently robust and rapid for routine work. Some alternative means of measurement was therefore sought.

Various schemes were tried and the one outlined below was selected as most suitable.



PATH OF LIGHT IN PHOTOMETER

FIG. 4

The light source is modulated at a suitable audio frequency by means of a motor-driven rotary shutter so that the output P.D. of the two cells (receiving light from the sample and standard surfaces respectively) contains alternating components of the same frequency. These alternating components are balanced against one another and the difference amplified considerably by a valve amplifier. The amplified difference is fed to a pair of head-phones or to a rectifier pattern low-reading A.C. volt-meter or both. In this way, the "matching" of the two surfaces is manifested by a null point in the output of the amplifier.

Under ideal conditions the null point so obtained should, of course, be a clean zero. In practice, however, a perfectly clean zero cannot be attained, though with proper precautions in design and adjustment the results are good enough to make possible under routine conditions an accuracy rather better than 1% for all except the darkest samples. (The principal factors involved in the obtaining of a clear zero point will be described presently.)

The complete instrument as set up for use is shown in Fig. 2. It is divided into two parts, the photometer proper, and the associated amplifier equipment. A discussion of the main technical features of the amplifier is given in the form of an appendix (page T120). Fig. 3 gives the main features of the photometer in plan and elevation respectively. Fig. 4 shows the path of the light through the instrument.

THE LIGHT SOURCE AND INTERRUPTER

The light source is an automobile headlamp bulb of 12-14 volts 48 watts, mounted horizontally and surrounded concentrically by the revolving interrupter which produces the light modulation.

The frequency of modulation is of some importance. If too low a frequency is used it will not be easy to amplify without interference, nor will it be easily audible; a very high frequency will also give trouble owing either to the high speed required for the shutter or alternatively to the large number of small elements it would require. Consideration of these and other factors led to the selection finally of a pitch of 512∿, which is easily reproducible by means of a standard tuning fork.

The interrupter itself is a short piece of glass tubing of sufficient diameter to surround the light bulb. On the outside of this tube parallel strips of silvering, blackened externally, alternate with similar strips of clear glass. A shutter of this description in which the material is continuous but the opacity intermittent, was adopted in order to avoid siren effects. The use of silvering to obtain the opaque strips enables the interior unblackened surfaces to act as reflectors, thus increasing the total illumination.

The division of the glass cylinder and the arrangement of the strips is carried out as accurately as possible. When associated with a fixed slit the 15 opaque strips on the glass cylinder produce 15 cycles of light variation per revolution, giving 512∿ when operated at 2048 r.p.m.

Some difficulty was experienced in obtaining glass tubing sufficiently true and free from striations for these requirements. Even the tube finally selected was appreciably out of balance mechanically and had to be corrected with small tinfoil strips cemented on the inside surfaces of the opaque parts of the tube.

The interrupter tube is carried by a chuck mounting on a steel shaft running in two white metal bushes. At the other end of the shaft is a governor of the brake type, somewhat similar to those used on gramophones, and also a flexible coupling to the small driving motor.

The shutter is surrounded closely by a fixed outer metal casing with perforated ends and a suitable slot for the light beam. Cooling is provided for by apertures and vanes on the chuck mounting which produce a powerful current of air past the lamp bulb. A view of the shutter with the outer casing removed is given in Fig. 5.

Even with these precautions for cooling, the temperature rise is rather great on prolonged continuous running. To minimise this a switch has been fitted and interlocked with the holder on which the fabric sample is carried, so that the bulb is only lit when a specimen is in place. This means in practice a reduction of at least 30% in the total heating. The lamp is fed by a small transformer rated at 15 volts through a control rheostat with a locking piece which normally limits the lamp voltage to 12, but whose removal enables the lamp to be temporarily over-run to 15 volts if necessary when measuring very dark surfaces. The switch coupled with the specimen holder is in the primary circuit of the lamp transformer.

The light after traversing the interrupter tube passes out through the slit in the casing and through a narrower slit into the photocell box. There is

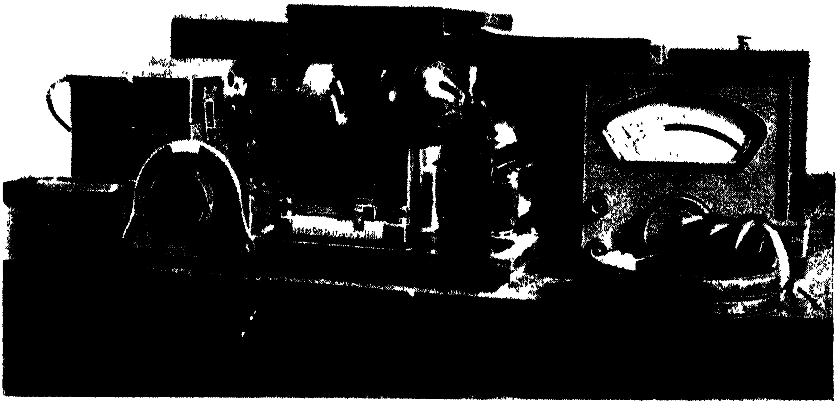


FIG. 2

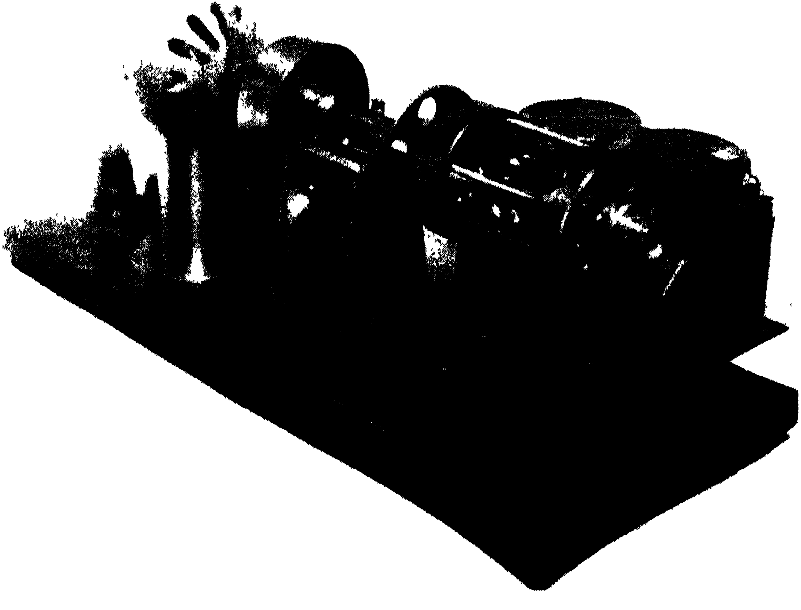


FIG. 5

provision at this point for inserting colour filters. The beam of light next impinges at an average angle of 45° on the two surfaces, which are on the base of the photo cell box. Diffusely reflected light from the two surfaces will thus reach the respective photocells, which are placed almost vertically above them. A system of partitions and diaphragms in the photocell box prevents the cells from receiving any extraneous light. The whole light system is arranged to be as nearly symmetrical as possible, though, of course, complete symmetry is only attainable when the whole of the standard surface is exposed so as to equal the area of the sample surface. This particular factor, however, can be taken care of in the calibration of the instrument.

The sample to be tested is placed in a suitably designed holder which stretches it lightly over a matt black surface and holds it with a light spring over the underside of an aperture, exactly 1 in. square, in the bottom of the "sample" side of the photocell box. "The standard" side of the photocell box has a similar aperture symmetrically placed, beneath which is fixed a block of pure plaster of paris as used for the "pure white" of the B.L.R.A. disc series. Originally the standard was made with the special white paint recommended in connection with the "cube" photometer, but this caused trouble by cracking. The plaster of paris, while not so white as the special paint, is actually whiter than any fabric likely to be measured, and moreover its surface can be readily renewed at any time by rubbing with fine glass-paper.

The "standard" aperture is arranged to be closed down to any required degree, its fourth side being formed by one end of a sliding shutter operated by a skew rack and pinion gear. The main scale of the instrument is mounted on the pinion shaft, which performs exactly one revolution for 1-in. movement of the shutter.

The main scale is not divided quite evenly, however, because the illumination of the standard surface is not uniform over its full extent. It has, therefore, been necessary to adjust the scale so that each division corresponds to an equal increment of light to the corresponding photocell. This adjustment was originally carried out on the results of calculation. The whole standard surface was divided into ten equal zones and the total light reflected from each zone on to the photocell was calculated, thus enabling nine intermediate points in the calibration curve to be fixed.

The scale as calculated was then checked by drawing a series of diagonally-ruled "trellis-work" patterns on a large scale on cards so that in each case there was a definite known ratio of black to white surface. The cards were then arranged together and photographed on a reduced scale on the one plate so that on a black and white print an area of about 1¼ in. square was obtained for each percentage, including all-white and all-black areas in order to obtain the two limits. These areas were now measured in the photometer, giving a series of values varying in a known manner between the two extremes, the black and white of the print. The results obtained were within 0·5% of the calculated values at every point, and gave no indication of the existence of any systematic error in the calibration.

The entry of dust to the photocell box or to the standard surface is prevented as far as possible by sealing all apertures with thin glass windows.

The two photocells are mounted interchangeably on the top of the photocell box in a metal cover which also carries the screened 3-way cable connecting the photocells to the amplifier. Spring clips and spring contacts make access to, and interchange of the cells a very simple matter, so that it is at any time possible to check the balance of the cells.

To correct for differences in the sensitivity of the cells, the more sensitive one may be reduced in sensitivity by the application of dead black paint to the central part of its aperture. This should not be done till after the cells have been corrected for phase errors (as described later).

The performance of the photometer varies somewhat, according to the brightness of the sample being tested.

For a bright sample the quantity of light reaching the "sample" photocell is considerable and the amount reaching the "standard" photocell at the balance point must of course be the same, so that any residual out-of-balance component tends to be proportionately greater than for a dark sample. This makes it desirable to reduce the light intensity for headphone working. Conversely for dark samples a higher light intensity is necessary. On the other hand, using the rectifier pattern A.C. voltmeter, a high light intensity may be employed satisfactorily throughout. It may be objected that dimming the light, by altering the light quality is liable to affect the results. This is certainly true, but the effect is important only for samples with marked dichroic characteristics, such as certain reds, blues, and violets, when working without colour filters in order to measure merely the relative "lightness" or "darkness" of the samples. Where actual colour determinations are made, using selective colour filters in the light beam the result is unaffected by the brightness or dimness of the light provided that there is sufficient light to give a proper reading.

For the evaluation of more or less neutral greys, the measurement of which was one of the primary purposes for which the instrument was designed, variations of brightness even over the extreme limits possible have no noticeable effect on the results. In the case of extremely dark samples (measuring less than 5% in terms of the standard white surface) it is necessary to increase the light to the maximum in order to obtain sufficiently large meter readings on the low side of the balance point. This sets a limit of the order of 2% in terms of the standard white surface to the darkest measurable sample. If the number of such extremely dark samples were considerable, however, it would be simple to deal with them by scaling down the whole instrument with a second standard surface adjusted to, say, 10% of the value of the principal one, but this has not so far been found necessary.

At the upper end of the scale there exists no such difficulty because the main standard is sufficiently bright that no fabric has yet been found measuring more than about 80% in terms of the standard white surface.

The value obtained directly from the photometer by this method of working is, of course, a ratio in which the diffuse reflective power of the sample is compared with an arbitrary standard within the instrument. This arbitrary value may be used throughout a series of observations, and will, of course, be strictly comparable. If a definite standard is desired, having reference to a particular piece of work in hand it is, of course, a simple matter to take the value for a particular sample (for example, the original untreated fabric in a series of dyeing tests), and call it unity, referring all the other values to it.

For the determination of colour values, the same scheme may be applied here as for other types of photometers. A set of three standardised colour filters is used covering the red-yellow end, the middle or green region, and the blue-violet end of the visible spectrum respectively, and the sample is measured with each filter in turn. As with other types of photometer this works quite well but the attainable accuracy is at present rather less than for "white" measurements owing to the smaller light intensities available. Work is, however, in progress for the improvement of colour measurements by increasing the amount of light available.

It is important to know the order of accuracy to be expected in routine work with the photometer. In Table I are given some typical results. These were taken on a random series of test fabrics under ordinary routine conditions except that in order to gain some idea of the amount of personal error involved they have been duplicated by two operators. The second operator had had more previous experience in working the photometer than the first.

Each sample has a surface area large enough to require several successive readings with a photometer to cover its area and the individual readings are made to the nearest ½%. The values actually reported in the Table are the averages of the individual readings, and the number of readings required for each sample is given in column 2. So far as the actual observations are concerned the possible accuracy of the average of a group of readings will under favourable conditions be rather better than ½%. In order, however, to facilitate later averaging of the different results and computation of the individual deviations from these averages all results have been reported to four significant figures. It is recognised that under ordinary conditions not more than three figures have any real significance.

The results as tabluated indicate that there is a tendency for the readings made when using headphones to be slightly higher than those obtained with the rectifier voltmeter, the latter being rather more consistent. There is also a slight personal difference between operators, and a somewhat greater degree of consistency in the results of the second, more experienced operator. Only three results (underlined in the Table) show deviations large enough to class them as abnormal; these all correspond to the less experienced operator.

On the whole, however, the table shows that personal and instrumental errors are not usually greater than ½%. It also appears that two closely similar samples may be differentiated provided they differ by about ½%.

In Fig. 6 is given graphically a series of typical voltmeter readings using normal illumination (full lines) and also using maximum illuminations with lamp over-run to 15 volts (dotted lines). These show the advantages of full illumination for the darker samples and also that the actual position of the minimum in the curve is not appreciably affected by differences in the illumination. (The samples on which these tests were carried out varied between blackish brown and pale grey in colour.)

It should be appreciated that the values at the minima are the resultants of the steady background noises and the differences due to imperfect balancing. While, therefore, the minima have larger values for the brighter surfaces they do not approach zero even for the darkest surfaces. This factor is no doubt to some extent responsible for the marked asymmetry of the curves. This asymmetry makes it important, when estimating the minimum position by taking equal readings above and below it, to choose the two points as close together as convenient.

When measuring dark surfaces using headphones, it is much easier to appreciate the exact position of the minima than would appear from the

Table I

Sample Number	Number of Readings to cover surface	Operator I			Operator II			Combined Averages			Deviations from Overall Average				Diff. between Operators Averages I–II	Diff. between Voltmeter and Phones Averages
		Phones (1)	Voltmeter (2)	Average	Phones (3)	Voltmeter (4)	Average	Phones (1) & (3)	Voltmeters (2) & (4)	Overall	(1)	(2)	(3)	(4)		
1	3	$11{\cdot}6_7$	$11{\cdot}3_8$	$11{\cdot}5_0$	$11{\cdot}5_0$	$11{\cdot}3_8$	$11{\cdot}4_1$	$11{\cdot}5_8$	$11{\cdot}3_8$	$11{\cdot}4_6$	${\cdot}2_3$	$-{\cdot}1_3$	${\cdot}0_4$	$-{\cdot}1_3$	${\cdot}0_9$	${\cdot}2_5$
2	3	$12{\cdot}3_3$	$12{\cdot}0_0$	$12{\cdot}1_7$	$12{\cdot}3_3$	$12{\cdot}3_3$	$12{\cdot}3_3$	$12{\cdot}3_3$	$12{\cdot}1_7$	$12{\cdot}2_5$	${\cdot}0_8$	$-{\cdot}2_5$	${\cdot}0_8$	${\cdot}0_8$	$-{\cdot}1_6$	${\cdot}1_7$
3	3	$\underline{15{\cdot}0_0}$	$13{\cdot}8_3$	$14{\cdot}4_1$	$13{\cdot}6_7$	$13{\cdot}6_7$	$13{\cdot}6_7$	$14{\cdot}3_3$	$13{\cdot}7_5$	$14{\cdot}0_4$	${\cdot}9_6$	$-{\cdot}2_1$	$-{\cdot}3_7$	$-{\cdot}3_7$	${\cdot}3_7$	${\cdot}5_8$
4	2	$24{\cdot}5_0$	$\underline{22{\cdot}7_5}$	$23{\cdot}6_2$	$24{\cdot}5_0$	$24{\cdot}2_5$	$24{\cdot}3_8$	$24{\cdot}5_0$	$23{\cdot}5_0$	$24{\cdot}0_0$	${\cdot}5_0$	$-1{\cdot}2_5$	${\cdot}5_0$	${\cdot}2_5$	$-{\cdot}7_6$	$1{\cdot}0_0$
5	3	$72{\cdot}0_0$	$\underline{73{\cdot}3_3}$	$72{\cdot}6_7$	$72{\cdot}0_0$	$72{\cdot}0_0$	$72{\cdot}0_0$	$72{\cdot}0_0$	$72{\cdot}6_6$	$72{\cdot}3_3$	$-{\cdot}3_3$	$1{\cdot}0_0$	$-{\cdot}3_3$	$-{\cdot}3_3$	${\cdot}6_7$	$-{\cdot}6_6$
6	4	$74{\cdot}7_5$	$73{\cdot}7_5$	$74{\cdot}2_5$	$74{\cdot}0_0$	$74{\cdot}3_7$	$74{\cdot}1_9$	$74{\cdot}3_7$	$74{\cdot}0_6$	$74{\cdot}2_1$	${\cdot}5_4$	$-{\cdot}4_6$	$-{\cdot}2_1$	${\cdot}1_6$	${\cdot}0_6$	${\cdot}3_1$
7	4	$76{\cdot}2_5$	$76{\cdot}1_3$	$76{\cdot}1_9$	$75{\cdot}5_0$	$75{\cdot}7_5$	$75{\cdot}6_3$	$75{\cdot}8_7$	$75{\cdot}9_9$	$75{\cdot}9_3$	${\cdot}3_2$	${\cdot}2_0$	$-{\cdot}4_2$	$-{\cdot}1_8$	${\cdot}5_6$	$-{\cdot}1_2$
8	4	$80{\cdot}0_0$	$79{\cdot}8_8$	$79{\cdot}9_4$	$80{\cdot}0_6$	$79{\cdot}9_4$	$80{\cdot}0_0$	$80{\cdot}0_3$	$79{\cdot}9_1$	$79{\cdot}9_7$	${\cdot}0_3$	$-{\cdot}0_9$	${\cdot}0_9$	$-{\cdot}0_3$	$-{\cdot}0_1$	${\cdot}1_2$

voltmeter curves. This is because the steady background noises which cannot be differentiated by the voltmeter are sharply distinguishable by ear; they take the form of a steady hiss as opposed to the clean musical note of the signal proper.

From these results the conclusion may fairly be drawn that the photometer is well suited for routine measurements of the type required in laundry control, and similar work.

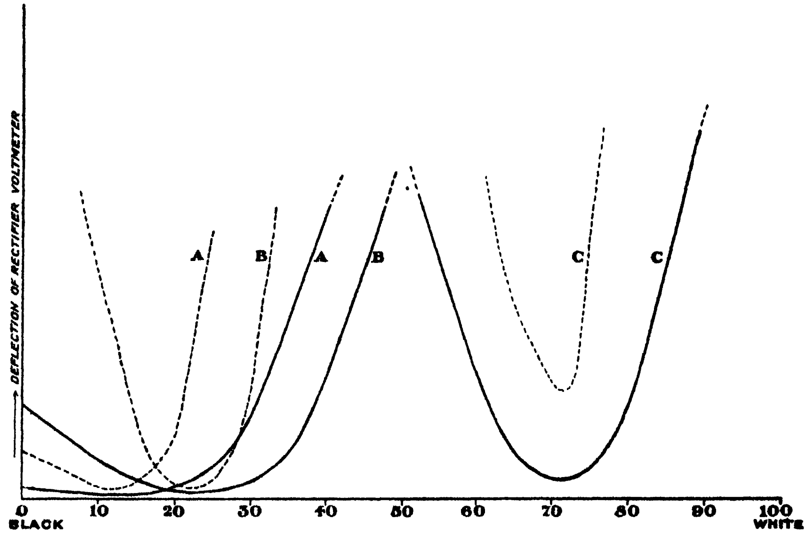


FIG. 6

It was mentioned earlier that the null point, though good enough to be useful, is not ideally sharp. A statement of some of the causes of this and the measures taken to remedy them may be of interest.

(*a*) Effects due to imperfect sensitivity of headphones or rectifier voltmeter for small signal values. It is well known that the human ear (and the eye also) is not responsive to stimuli having less than a certain fairly definite "threshold" value. The rectifier voltmeter, similarly, is not responsive to A.C. potential differences of R.M.S. value much less than about 0·3 volt though it is quite sensitive to minute differences in P.D. at (say) 0·4 volt. Another cause of this effect is the failure of the iron-cored components in the amplifier to function properly for input voltages below a certain minimum. Actually this effect is minimised by avoiding iron-cored apparatus until after the first stage of the amplifier. The result of this is that the curve plotted for meter readings (or apparent audibility on headphones) in the neighbourhood of the balance point is not so much "V" shaped, which would be ideal, as trough shaped, there being a more or less broad minimum zone within which differences are not perceptible. This effect is minimised by increasing the overall gain of the amplifier as far as other factors permit.

(*b*) Effects due to background noises. These may be derived partly from imperfections within the instrument (such as slight errors in the division of the light interrupter), and partly from the amplifier, which may pick up interference from the mains and may also be subject to microphonic or other noises due to the valves. The combined effect of these causes is the production of a definite background noise in the phones and a definite "blank" deflection of the meter. The noises in the phones are annoying and reduce sensitivity. The "blank" deflection of the meter, so long as it is fairly steady and free from fluctuations due to mains irregularities, may actually improve sensitivity materially by "stepping up" the readings, so that the threshold effect described above, in as far as it is due to the rectifier characteristics, is avoided.

(*c*) Effects due to imperfect coincidence of the opposed output P.D.'s of the two photocells. For a perfect zero the output P.D.'s of the two cells must be equal at every instant, which involves not only equality of the P.D.'s in amplitude but also identity in phase and wave-form.

Phase differences may be due to actual differences in phase in the light on the two sides of the photometer. The most likely practical causes of this are (*a*) lack of parallelism of the interrupter strips and the slit on the photocell box and (*b*) skewness of the lamp filament.

It is fairly simple to eliminate these mechanical causes but the electrical causes of phase difference are more difficult to deal with.

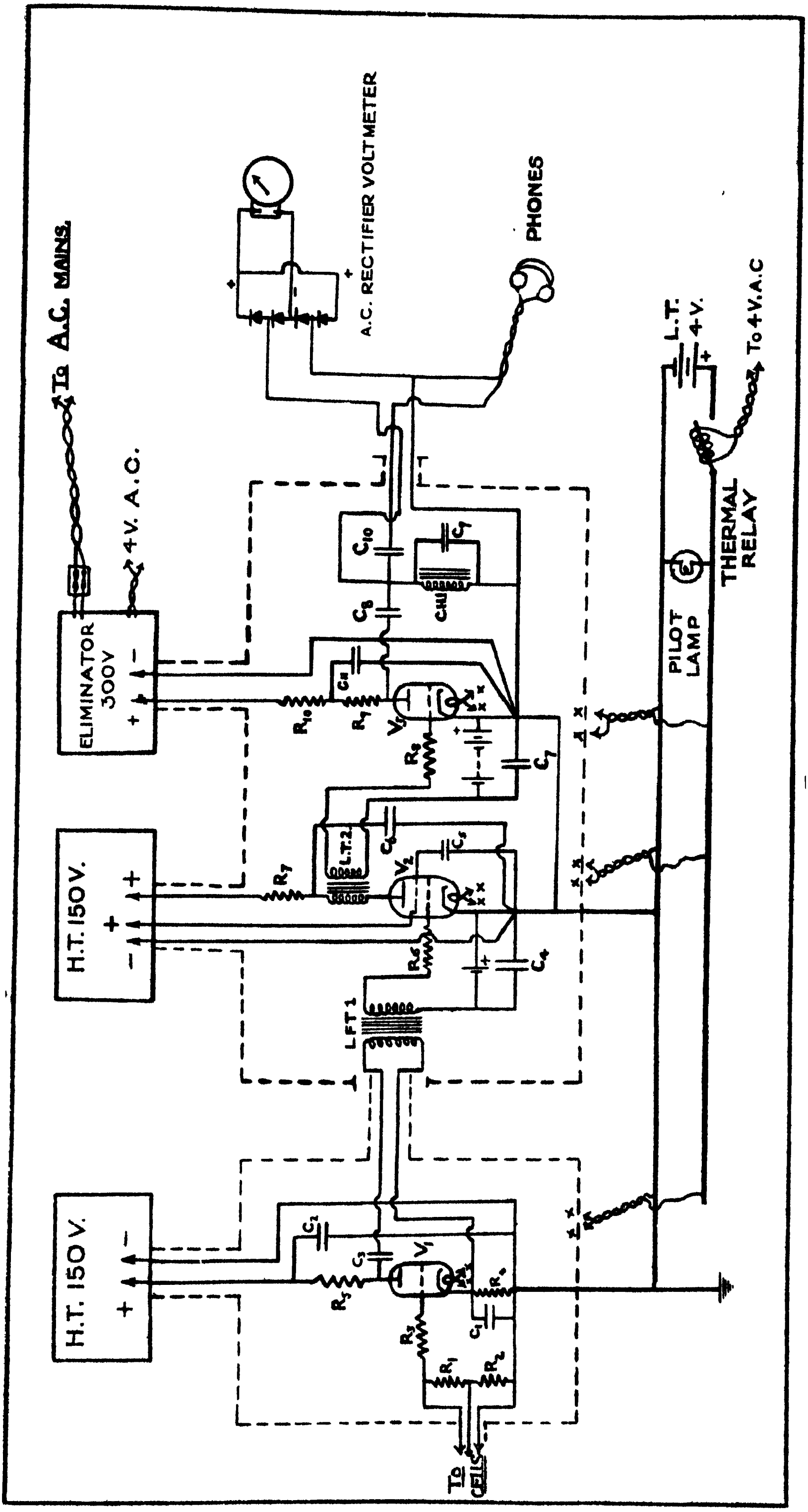
The electrical behaviour of a photocell is found when analysed to be very complex. The cell behaves somewhat as though it consisted of a low resistance in shunt with a condenser, the value of both of these being, however, to some extent variable with the output P.D. owing to internal "rectifier" effects. Assuming that the "internal" E.M.F. due to the light is strictly in phase with the light variations, the capacity of the cells produces an internal loading and a consequent phase retardation of the resultant external P.D. across the cell terminals of value $\tan^{-1}(2\pi NCR)$ (where N is frequency in cycles per second, C capacity (in farads) and R is resistance (in ohms)).

Owing to the lack of constancy of C and R mentioned above, the implications of this relationship cannot be pushed too far, but it is clear that the phase angle for a given cell and frequency is determined by the value CR and that differences can be compensated within certain limits by the use of external condensers and resistances.

For the particular cells employed on the photometer constructed, a phase correction condenser of about 0·45 microfarad across one cell gives about the best balance. It is evident, therefore, that considerable phase differences may exist if correction condensers are not employed.

Another effect of a similar type to the phase differences discussed above, is that of difference of wave-form. Unfortunately the wave-form of the modulated light is not sinusoidal (being in fact rather like that of a machine screw thread profile) and hence harmonics of the fundamental frequency are present in the internal E.M.F. of the photocells. The proportion and phase relations of these harmonics will naturally be disturbed by the self-capacity of the cells so that the wave-forms of the two cell outputs do not necessarily agree.

One obvious way out of this difficulty is to use selective circuits in the amplifier so that the output finally used is due to the pure fundamental only. The balance point obtained under these conditions will be unaffected by the harmonics, provided that no rectification has occurred in the amplifier prior to, or during the removal of the harmonics. Otherwise, by the recombination of different harmonics, with rectification, the fundamental may easily be reintroduced.


To A.C. MAINS
4V. A.C.
ELIMINATOR 300V
+ + −
H.T. 150V.
+ + −
H.T. 150 V.
+ −
A.C. RECTIFIER VOLTMETER
PHONES
L.T. 4V.
To 4V.A.C
THERMAL RELAY
PILOT LAMP
C10
C9
CH
C8
C11
R10
R9
V3
R8
C7
C6
L.T.2
R7
V2
C5
R6
C4
LFT1
C2
C3
V1
R5
R4
R3
C1
R1
R2
To CELLS

To avoid the risk of this, it is obviously best to filter out the harmonics as early as possible in the amplifier, before the signal amplitude has become big enough for appreciable rectification. This is unfortunately not feasible. Iron-cored tuned circuits cannot be operated with the extremely small signal amplitudes involved near the null point while air-cored inductances of low decrement for 512∿ are extremely bulky and difficult to screen.

It was, therefore, necessary to design the amplifier to avoid rectification as far as possible and to isolate the 512∿ fundamental at the output stage by a selective iron-cored output circuit. The action of this is reinforced by the use of headphones embodying reeds tuned to 512∿ and loose-coupled to the filter circuit. It is noteworthy that the presence of the headphones in the circuit appreciably improves the performance of the rectifier type voltmeter.

In view of the fact that the amplifier is necessarily operated partly from the mains and partly from three different batteries some consideration was given to simplifying the operations necessary when switching on or off. Two of the batteries are high tension dry batteries for the first two stages of the amplifier. It was decided to avoid complications here by leaving them permanently in circuit with, of course, suitable protective fuses. The third battery is the 4-volt accumulator supplying the cathode heaters of the three valves. The current from this battery is fairly large and it was, therefore, decided to avoid risk of it being left in circuit unnecessarily by coupling it to the mains circuit with a relay. This relay is thermally operated, a small heater being connected to an otherwise unused 4-volt winding on the supply transformer of the H.T. mains unit which feeds the output valve of the amplifier. The arrangement is completed by the provision of a small low-consumption pilot lamp in the battery circuit, which not only serves as a check on the correct working of the relay, but also gives warning if through carelessness the batteries are allowed to discharge completely.

DESIGN OF THE AMPLIFIER AND ITS ASSOCIATED COMPONENTS

The complete amplifier circuit with component values is given in Fig. 7 The purpose of the amplifier is to amplify a very small signal of the order 10^{-10} volt at 512∿ with an overall gain of approximately $1{\cdot}5 \times 10^{6}$, sufficient to operate a pair of headphones audibly or to give a perceptible deflection on a rectifier voltmeter. It is important to avoid the amplification of other frequencies and to ensure the absence of background noise as far as possible so that the 512∿ signal may not be masked. From what has already been said it is clear that the amplifier must be selective to 512∿, i.e. it must contain a tuned circuit of some type. For reasons already given this tuned circuit must also be in the output stage.

The small amplitude of the signal when working close to the balance point determines the nature of the valve couplings to be used and also largely determines the choice of the valves. In spite of the low impedance of the photocells it is not feasible to employ any step-up device at the amplifier input. The cells are, therefore, merely connected in series opposition between the grid of the input valve and the source of the grid bias. This arrangement is not perfectly symmetrical with respect to stray capacities, but the errors so introduced are not appreciable owing to the high self-capacities of the photocells. It is the recommendation of the photocell manufacturers, that the cells are each shunted by a high resistance (10,000 ohms), in order to avoid damping each cell output by the output P.D. of the other cell. Owing to the high input impedance of the first valve and the low impedance of the photocells it is doubtful, however, if any material advantage is gained by the use of these resistances.

Since the first valve has to deal with such an extremely small signal it is imperative that this valve shall amplify with minimum introduction of noise. Screen-grid valves are by far the most efficient type for amplification at a single frequency, but unfortunately they are usually far more noisy than triodes owing to secondary ionisation, which produces a steady hissing sound. Tests showed that a triode of high magnification value gave the best all-round results in the first stage, provided that microphonic effects could be avoided. This was best done by the use of indirectly-heated cathode valves of the A.C. mains type.

The high stage-gain obtainable by the use of A.C. mains valves throughout is, of course, an advantage but it has necessitated the use of drastic methods to avoid interstage couplings. Further, in order to ensure absence of mains interference, high tension, grid bias, and heater supplies for the first and second valves must be derived entirely from batteries. To avoid interstage couplings each valve has, of course, its own grid bias supply. In addition, care has been taken to arrange each circuit associated with the valves so as to commence and terminate with the cathode of the valve concerned, and to dispose the wiring of each circuit so as to offer the minimum loop area, thus minimising inductive coupling.

After experiment it was decided to build the first stage within its own screen box and to connect it with its own screened H.T. dry battery by a screened lead. The second and third stages were included in a second screen-box, the second stage deriving its H.T. from its own dry battery in a similar way to the first stage. Only in this manner could the requisite high margin of stability for quiet operation be obtained.

Owing to the higher amplitude of signal at the second stage, the use of a screen-grid valve is permissible. The first interstage coupling is a "parafeed" transformer with a special alloy core, resistance-capacity coupled. The second stage coupling is a Ferranti A.F.3 transfromer directly coupled into the anode circuit of the screen-grid valve. To avoid parasitic oscillations a 50,000 ohms resistance is connected in each valve grid lead.

The use of a third separate H.T. battery for the output valve is avoided by supplying this valve from a mains unit, though even here it was necessary to use an unusual amount of smoothing to avoid noise, which involved rectifying nearly 300 volts to obtain an effective 120 volts.

7—SPIRALITY IN KNITTED FABRICS

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INTRODUCTION

In a hosiery fabric knitted in a plain stitch, the lengthwise rows of stitches, called needle lines or wales, should occupy a truly vertical line in the fabric and should always be at right angles to the crosswise courses of stitches. This frequently is not the case and many types of knitted fabric in wool or cotton show a pronounced bias towards the left or the right, which appears in the form of a twilled surface. For convenience ot description this defect has been termed "spirality" of knitting, since it occurs chiefly in circular fabric. Examples of this defect are shown in Plate I, where (*a*) is a normal straight fabric, while (*b*) and (*c*) are fabrics with a bias to the left and the right respectively.

This fault has been encountered in the hosiery trade for many years and, although it has been shown to depend in some measure on the texture of the fabric and also on the type of yarn used, the actual cause has remained obscure. Various methods have been adopted for overcoming this defect but they have all been directed towards removing the spiral effect from the fabric rather than preventing its formation. When the twilling is not too severe it may be temporarily corrected during the process of steam pressing by forcing the fabric or garment to lie straight on the board as it enters the press. The strain imposed on the fabric is only temporarily set by this treatment, and is immediately released again on washing the garment or hose which turns on its own axis in corkscrew fashion, with consequent loss in appearance and discomfort in wear.

As a result of prolonged researches in co-operation with the Wool Industries Research Association, who have supplied series of yarns in all ranges of twist, we are able to state that the spirality is caused mainly by the amount of twist in the yarn. The apparent effect of other factors is due to any small modifications which they make in the original cause.

A representative range of wool yarns has been tested, both normal and reverse twist, with turns per inch varying from 6 to 20, and spun from botany and crossbred qualities. In every case the spirality increases directly with the yarn twist, takes a left or right direction in accordance with the yarn twist, and is increased by slackening the texture of the fabric.

EXPERIMENTAL

For the purpose of measuring the angle of spirality, the yarns were all knitted into tubular fabric on an automatic circular hose machine. This was a Scott & Williams' machine of the "B5" type with a needle cylinder of diameter 3¾ in. carrying 220 latch needles; the spacing of these round the circumference of the cylinder is 18·7 per inch. The normal direction of rotation of the cylinder is anti-clockwise. Three different fabric textures, obtained by adjusting the loop-forming parts to change the stitch length, were used and each sample of yarn was knitted into three lengths of fabric, having 27, 30, 36 courses per inch respectively. These fabrics represent slack, normal, and tight knitting on this type of machine. Each length of fabric was separated from the next by a short length of cotton and was also divided similarly into two parts. These samples were allowed to stand for a few days after knitting, before measurement of the spirality, in order to allow any strains to adjust themselves. The angle of spirality was measured by placing a large protractor on the flat fabric, with its base line along a course, and by reading the angle of the needle line from the vertical. A series of readings was made along each sample and the mean of these taken as the true angle of spirality.

The actual twist of the yarns as spun was determined directly on the frames by the stroboscopic method. This twist was, however, modified in both the winding and knitting processes since the yarn was drawn off from the end of the cop and the bobbin in each case. The amount of this alteration varies according to the position of the yarn on the package, but a mean correction was obtained by measurement of the effect on a long length of yarn drawn off. Drawing either *normal or reverse twist yarn off its cop inserts 0·31 turns per inch into the twist, since the yarns were wound and are also drawn off in opposite directions. Drawing any yarn off the type of bottle bobbin used inserts 0·18 turns per inch of normal twist, since the winding spindles always rotate in a clockwise direction as for spinning a normal twist yarn. This correction must, therefore, be added to the normal twist and subtracted from the reverse twist yarns. The total corrections for processing are—

To normal twist add 0·50 turns per inch.
To reverse twist add 0·15 turns per inch.

The corrected turns per inch have been used throughout all results given in this paper.

The first set of experiments was made with a 1/24's botany yarn spun from a 64's quality top. The values for the turns per inch and corresponding angles of spiral are given in Table I and the relationship of these is illustrated in Fig. 1.

Table I

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spirality (to right)		
7·15	9	10	4
9·00	17	12	5
10·70	25	16½	9
12·50	29	22½	15
14·20	34	28½	18
16·65	36	34	21
Reverse Twist	Angle of Spirality (to left)		
6·80	6	6	6
8·65	11½	10½	9½
10·35	19	15	12
12·15	25	22	14
13·85	31	24½	18
16·30	35	31	27

This graph clearly shows the close relationship between the twist and spirality. Normal twisted yarn always produces a fabric with a bias to the right and *vice versa,* and slackening the texture of the fabric increases the effect by lengthening the sides of the loops, so permitting greater lateral movement of the courses of stitches relative to each other.

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*NOTE—Normal twist yarn refers to the ordinary hosiery single yarn which has its twist in the direction of a right screw. Reverse twist is in the opposite direction.

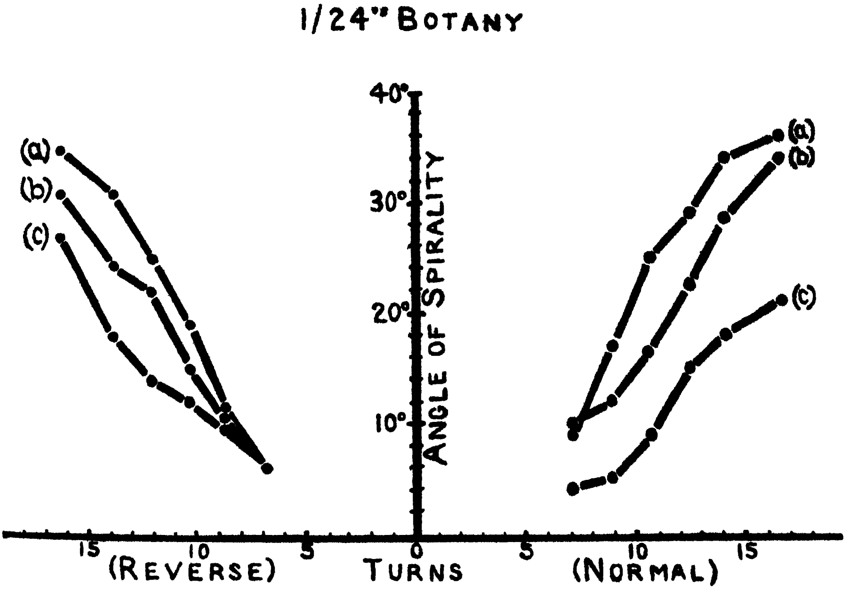


FIG. 1

(a) = Slack texture
(b) = Medium texture
(c) = Tight texture

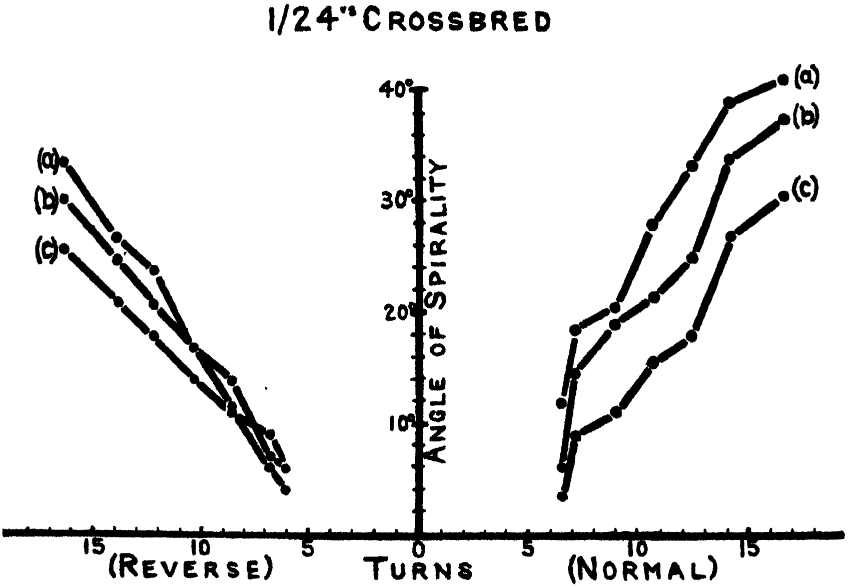


FIG. 2

(a) = Slack texture
(b) = Medium texture
(c) = Tight texture

It might be expected that the more wiry properties of crossbred wool would cause an even greater effect than was found for botany wool and this was found to be true. For this purpose a range of 1/24's yarns was spun from a 56's crossbred quality and was knitted up as before. The results are given in Table II and the relationship is illustrated in Fig. 2.

Table II

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spiral (to right)		
6·50	12	6	3½
7·15	18½	14½	9
9·00	20½	19	11
10·70	28	21½	15½
12·50	33½	25	18
14·20	39	34	27
16·65	40½	37½	30½
Reverse Twist	Angle of Spiral (to left)		
6·15	4	6	6
6·80	6	7	9
8·65	11½	14	11
10·35	17	17	14
12·15	24	21	18
13·85	27	25	21
16·30	34	30½	26

The curves are somewhat steeper than for the botany yarns and the corresponding values higher, but the general form remains the same. Over the range of twist values used, the angle of twist is almost proportional to the number of turns per inch, so that the angle of spiral in the fabric varies directly with the angle of twist in the yarn.

PREVENTION OF SPIRALITY

We have already mentioned in the introduction that moderate spirality in a fabric can be suppressed by setting the fabric with heat in the steam press, but that the result is temporary and unsatisfactory. If the setting is made permanent by the direct application of steam a much better effect can be obtained and there is an obvious opening here also for the crabbing process as applied to woollen piece goods. If the original fabric shows much spirality the result of such treatment as described above may be to give it a strained appearance and it is better actually to prevent the formation of the spirality. For this reason it was decided to render the twist in the yarn inoperative, by setting the yarn before knitting, both steam and water being used for this purpose.

A batch of botany and of crossbred yarns exactly similar to those already described, were spun on setting bobbins and equally divided into two lots. One half was water-set by boiling for 20 minutes, plunging into cold water, hydro-extracting and drying. The second portion was steam-set by steaming the cops for 60 minutes in a closed vessel, hydro-extracting and drying. Both sets were then conditioned for four days before knitting. The two batches of yarns were knitted and the spirality of the fabrics measured as described for the untreated yarns. The corrections of the twist for the winding and knitting processes remained exactly as before, but it should be noted that this additional twist had not been set and was operative in producing spirality. The results for the 1/24's botany yarns are shown in Tables III and IV.

Table III—Water Set

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spirality (to right)		
6·50	0	−1	−1
7·15	0	− ½	− ¾
9·00	¼	− ¼	− ¼
10·70	0	¼	− ½
12·50	½	¼	0
14·20	1½	0	0
16·65	2½	1	0
Reverse Twist	Angle of Spirality (to left)		
6·15	¼	0	1½
6·80	0	0	½
8·65	¾	0	1
10·35	1	−½	¼
12·15	1	−½	1¾
13·85	1	0	1½
16·30	1¾	¼	2½

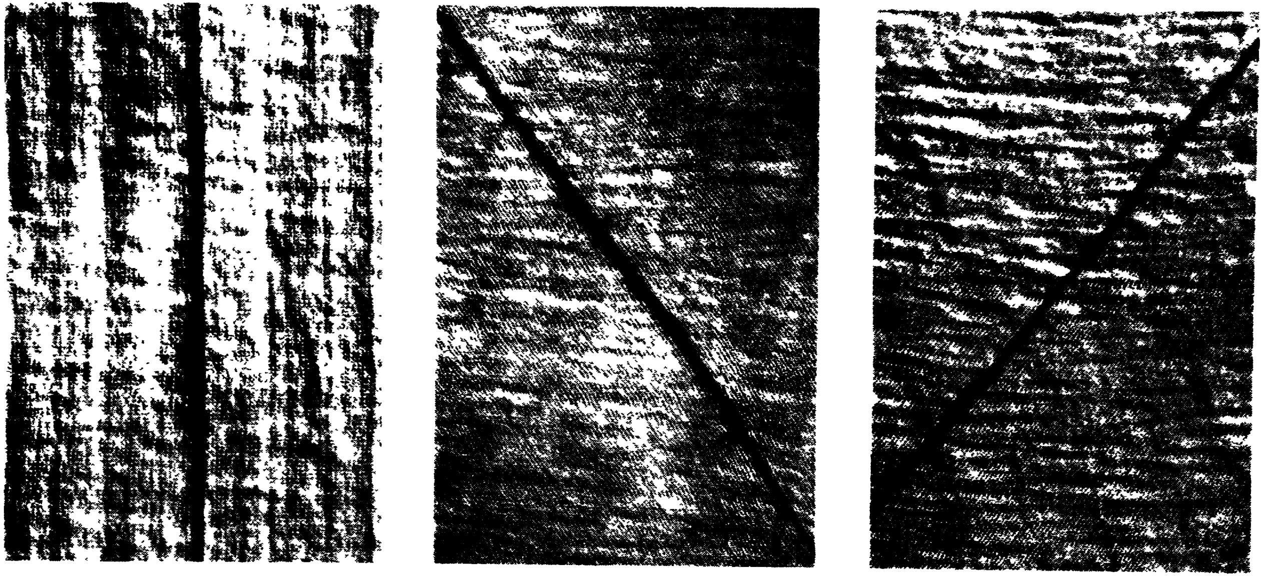
Table IV—Steam Set

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spirality (to right)		
6·50	¾	−½	−2
7·15	½	0	− ½
9·00	1½	0	0
10·70	2	0	0
12·50	2½	¾	¼
14·20	3¼	¾	0
16·65	4¾	2¼	1¼
Reverse Twist	Angle of Spirality (to left)		
6·15	−½	¼	1
6·80	1	¼	½
8·65	1¼	¾	¼
10·35	¾	¾	1¾
12·15	1¼	1	2
13·85	1¼	1¼	2
16·30	1¾	1¾	2½

The spirality of these fabrics shows a very marked reduction from that obtained by using the untreated yarn, and yarn setting is evidently the best remedy. The superiority of water setting over steam setting is quite definite and water setting is also to be preferred because it causes less discoloration of the yarn. This effect is still more noticeable in the case of crossbred yarns, which are evidently more difficult to set. The results for 1/24's crossbred are given in Tables V and VI.

Table V—Water Set

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spiral (to right)		
7·15	2½	0	0
9·00	3	0	0
10·70	4	½	0
12·50	3	0	0
14·20	4½	½	¼
16·65	4	1½	1
Reverse Twist	Angle of Spiral (to left)		
6·15	− ¾	0	1
6·80	−1¼	0	½
8·65	0	0	½
10·35	0	¼	½
12·15	−¼	0	¾
13·85	−¼	0	¾
16·30	−¼	1¼	¾



(a) (b) (c)

PLATE I

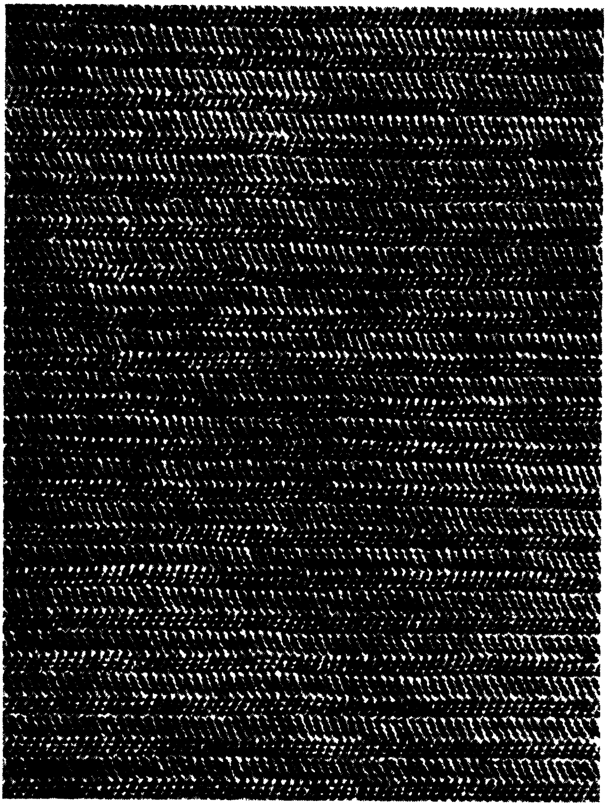


Plate II

Table VI—Steam Set

Turns per inch	27 c.p.i.	31 c.p.i.	36 c.p.i.
Normal Twist	Angle of Spiral (to right)		
7·15	4	1	−1
9·00	4½	1	0
10·70	6	1½	½
12·50	6¼	1½	1¾
14·20	7¾	3½	1½
16·65	8	3¼	2
Reverse Twist	Angle of Spiral (to left)		
6·15	0	1	1
6·80	0	¼	2
8·65	¼	¾	2¾
10·35	¾	2	2
12·15	¼	2	1½
13·85	1¼	1½	2¼
16·30	1½	3¼	2½

EFFECT OF TWO YARNS

If two ends of yarn of equal and opposite twist are knitted together, it will be expected that their tendencies towards the production of spirality will exactly neutralise, and a straight fabric will result. Further, this theory can be extended to the production of a doubled yarn whose twists are so balanced that it gives the same effect as two threads of equal and opposing twists. This field was thoroughly explored by using 1/48's botany yarn spun from the same top as the previous set of 1/24's botany yarn in a corresponding higher range of twists. 1/48's count was chosen for this purpose because two ends are of suitable gauge for the same machine as previously used. Since the effect of fabric texture on the spirality has been established in the former series of experiments all the 1/48's yarns were knitted into slack texture fabric at 27 courses per inch, in order to show the maximum angles for measurement.

The first experiments consisted of knitting two ends of the 1/48's botany, of the same direction of twist and number of turns per inch, for comparison with the results from the 1/24's botany. Table VII shows the figures obtained from a range of five different twists.

Table VII

Turns per inch	27 c.p.i.
Normal Twist	Angle of Spiral (to right)
14·20	22
15·20	25
16·40	28½
17·80	32½
19·40	38
Reverse Twist	Angle of Spiral (to left)
13·85	24
14·85	24½
16·05	25½
17·45	32
19·05	34½

These results give a curve of similar outline to those of Figs. 1 and 2 although the range is more restricted. If, further, the values of twist in the 1/24's yarn corresponding to those of the 1/48's yarn are calculated, by dividing the latter by 1·414 ($\sqrt{2}$) according to the accepted principle, it becomes possible to compare the angle of spirality produced by the same angle of twist on different counts of yarn, *e.g.* two ends of 1/48's yarn of 15·20 turns per inch produce a fabric which has a spirality of 25°. The corresponding twist on a 1/24's yarn is 15·20/1·414=10·75 turns per inch, and, from Table I, a 1/24's botany yarn of 10·70 turns per inch also gives a fabric of spirality 25°. This agreement is close and indicates the relationship between angle of spirality in the fabric and angle of twist in the yarn, irrespective of the count.

A corresponding series of setting tests was also made with these yarns, using the processes of water-setting and steam-setting exactly as previously described. The results, shown in Table VIII, were very satisfactory, the spirality being reduced below 1° in all cases.

Table VIII

Turns per inch Normal Twist	Water Set	Steam Set
	Angle of Spiral (to right)	
14·20	0	−½
15·20	0	−¼
16·40	0	−¼
17·80	0	0
19·40	0	0
Reverse Twist	Angle of Spiral (to left)	
13·85	−¼	¼
14·85	½	¾
16·05	½	¾
17·45	½	¼
19·05	½	¼

EFFECT OF OPPOSING TWISTS

All three types of yarn were used in this series, various pairs of yarns, in different combinations, being knitted together. These included pairs of opposite and equal yarns and also pairs of opposite and unequal yarns, a representative range of the possible permutations being selected. It should be noted, that, on account of the difference between the corrections for

Table IX

Turns per inch Normal Twist	Turns per inch Reverse Twist	Angle of Spiral
	48's Botany Yarn	
14·20	13·85	1¼ Right
16·40	13·85	2½ ,,
19·40	13·85	5 ,,
14·20	15·85	0 ,,
16·40	15·85	1¾ ,,
19·40	15·85	4½ ,,
14·20	19·05	1½ Left
16·40	19·05	1½ ,,
19·40	19·05	2¼ Right
	*24's Botany Yarn	
7·15	6·80	2 Right
9·00	8·65	2 ,,
10·70	10·35	1 ,,
12·50	12·15	2 ,,
14·20	13·85	3 ,,
16·65	16·30	4 ,,
16·65	6·80	12 ,,
7·15	16·30	8 Left
	*24's Crossbred Yarn	
7·15	6·80	0
9·00	8·65	0
10·70	10·35	0
12·50	12·15	0
14·30	13·85	0
16·65	16·30	0
16·65	6·80	11 Right
7·15	16·30	11 Left

---

* Note—On account of the greater thickness of two ends of 1/24's yarn, these samples were knitted on a "George" machine having 14 needles per inch.

winding to be applied to the twist for normal and reverse twist yarns, it was impossible to get a pair of yarns of exactly opposite and equal twist, and this effect shows up in such cases as a small bias to the right. The results of these tests are grouped in Table IX and are in good agreement with the theory. Where the pairs of yarns have opposite but unequal twists, the direction of the spirality is that given by the yarn of higher twist, but its value is, of course, less than that to be expected from such a yarn when knitted alone. This value corresponds approximately to the algebraic mean of the spiralities given by the two yarns when knitted separately, but it has been impossible to pursue this matter further since the maximum spirality is given by use of the pair of yarns from opposite ends of a range, and the difference between such extremes is necessarily limited.

DOUBLED YARNS

There are obvious practical difficulties in the way of knitting together yarns of different twist, since this would involve a system of contrasted marking for normal and reverse twist yarns and the necessity of keeping them separate. There is, however, a wide field for the use of doubled yarns in knitted goods and an investigation of their properties was made. The effects of the singles twists and of the doubling twist have been considered separately and, for this purpose, three lots of 2/48's yarn were prepared, an original single yarn of 13·70 turns per inch twist being used as the foundation for each doubling.

(*a*) Two normal singles folded in the direction of the singles twists with a range of doubling twists.

(*b*) Two normal singles folded in the opposite direction to the singles twists with a range of doubling twists.

(*c*) A normal and a reverse singles folded in the direction of the reverse single yarn with a range of doubling twists.

These samples were knitted on the same machine as before and the resultant spiralities are given in Table X.

Table X

Turns per inch Doubling Twist	Angle of Spirality		
	(*a*)	(*b*)	(*c*)
2·37	24 Right	17 Right	¼ Left
3·39	29 ,,	15 ,,	2½ ,,
4·46	31 ,,	14 ,,	5½ ,,
5·46	34 ,,	12 ,,	8½ ,,
6·53	36 ,,	9 ,,	13 ,,
7·52	37 ,,	5 ,,	14 ,,

The curves relating these figures are illustrated in Fig. 3, and they prove that the effects of the singles and doubling twists can all be considered separately. Curves (a) and (b) are nearly symmetrical about a line through 20½° parallel to the axis of twist, 20½° being the spirality value obtained by knitting two ends of 1/48's yarn of 13·70 turns per inch normal twist (by extra-polation of Table VII). The doubling twist adds or removes spirality from this basic figure according to its direction relative to the singles twist. Curve (c) is virtually a relation of spirality to doubling twist since the opposing singles here neutralise, and this curve can be used to obtain the value to be added to or subtracted from the spirality due to its singles.

DOUBLED YARNS FREE FROM SPIRALITY

Having established the principles governing the behaviour of doubled yarns, the figures of Tables IX and X are sufficient to calculate the data necessary for the production of folded yarns free from any spiral tendencies. The doubling twist necessary in the yarn for the type of fabric required is first decided, and its resultant spirality determined from Fig. 3 (c). Two single yarns of opposite but unequal twist are then to be selected, the yarn of lower twist being spun in the direction of the doubling twist. The actual twist of these yarns may be suited to the occasion, but the difference of their twists must be sufficient to produce a spirality exactly equal and opposite to that caused by the folding twist, *e.g.* in Table IX, a normal yarn of 19.40 turns per inch knitted with a reverse yarn of 13·85 turns per inch gave a fabric with spirality 5° right. The folding twist necessary to counteract this would be about 4·3 turns per inch.

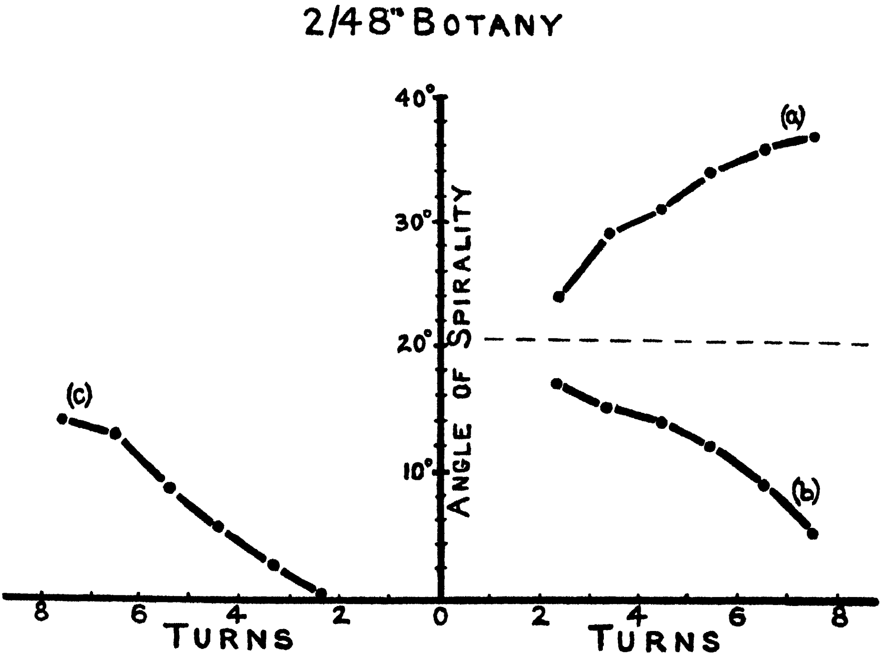


FIG. 3

This was verified experimentally on two series of yarns of this type, doubled in a range of twists—

(*a*) 13·7 Turns per inch normal twist folded with 18·9 turns per inch reverse twist.

(*b*) 18·9 Turns per inch normal twist folded with 13·7 turns per inch reverse twist.

These yarns were knitted into fabrics as before and the resultant spiralities are given in Table XI.

Table XI

Turns per inch Doubling Twist	Angle of Spirality (*a*)	(*b*)
2·37	1 Left	3¼ Right
3·39	1¼ Right	1½ ,,
4·46	5¼ ,,	2½ Left
5·46	8½ ,,	6 ,,
6·53	10¾ ,,	8 ,,
7·52	12 ,,	9 ,,

In each of these series there is a change from right to left in the direction of the spirality, indicating that a balanced yarn is possible by proper selection of the respective twist values.

CONCLUSION

A note on the effect of the knitting machine action on spirality may prove of interest. The machine used for these experiments has a stationary cam system and a revolving cylinder which always rotates in an anti-clockwise direction and it was suggested that this might affect the spirality by always producing a small residual bias in one direction. To test this effect, samples of normal and reverse twist yarns were knitted as usual, after which the cam system and drive were so adjusted as to rotate the machine in the opposite direction, knitting the same samples of yarn as before. With a normal twist yarn the spirality increased from 31° right to 32°, while with a reverse twist yarn it remained constant at 27° left. Evidently the machine effect on the spirality is negligible.

It was also found that the yarns rapidly acquired a temporary setting on storage under favourable conditions, and, for this reason, all samples used in this work were knitted immediately on delivery. A yarn knitted within a week of spinning gave a spirality of 28°; after storage for four months the same yarn produced only 13½°. The two fabrics were then soaked in water at 100° F. and allowed to dry. On re-measurement of the spirality, the 28° was reduced to 27½° while the 13½° increased to 21°, showing that the setting effect has been quite large.

The evidence described in this paper seems quite conclusive that the spirality of knitted fabrics is due to yarn twist, and that it may be reasonably prevented by setting the yarn to render the twist inoperative, prior to knitting or by the use of suitably balanced doubled yarns. This should have wide applications in hosiery manufacture, since we have been approached with several examples of this defect during the course of this work. The setting of yarns, particularly by steam, is an easy and old-established process in other sections of the textile industry and its extension to this branch should not prove difficult.

An interesting application of the spiral effect is its use for the production of fancy fabrics, by using yarns of different twist on a multi-feeder machine. For example, by knitting four threads of normal twist and four of reverse twist yarn consecutively on an eight-feeder machine, a fabric closely resembling the familiar "shadow stripe" fabric of the warp loom can be made. An illustration of such fabric is shown in Plate II. Similarly by knitting alternate ends of normal and reverse twist yarn quite a successful imitation of crêpe fabric is possible. The connection between this and the method of production of woven crêpe fabrics is very illuminating.

In conclusion, our particular thanks are due to the Wool Industries Research Association, who have made this work possible by their active co-operation and help in spinning all the necessary yarns. We also make acknowledgement of the valuable assistance given by other members of our staff.

SUMMARY

(1) Spirality is caused mainly by twist in the yarn. It increases uniformly with this twist and takes the same direction.

(2) The effect is generally higher for crossbred yarns than for botany yarns of the same characteristics.

(3) The effect can be corrected only temporarily by treatment of the fabric in the steam press.

(4) The defect can be almost completely prevented by previous setting of the yarn. Water-setting is rather more effective than steam-setting.

(5) Where two ends of yarn are to be used, spirality will not be evident if the single yarns have equal and opposite twists.

(6) Suitably balanced two-fold yarns can be constructed to give fabric free from spirality.

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8—ABRASION TESTING OF KNITTED TEXTILES

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(University College, Nottingham)

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Various methods of conducting tests for wear on textiles have been devised, but these have for the most part had particular reference to woven fabrics. A suitable method of assessing the wearing power of the knitted fabric is of interest to this branch of the industry. The apparatus, described herewith, has been designed by Buckley as being specially adapted for testing the wearing properties of knitted fabrics by the methods of rubbing or abrasion. The rubbing is produced by a to-and-fro action of a rubbing arm acting on a test piece of the fabric. An important factor in the method is the use of an inflated ball over which the test piece is placed so that the surface yields under the action of the rubbing arm. This abrasion surface is curved and it is suggested that the action reproduces those conditions in actual wear which correspond to rubbing at knees or elbows.

A diagram of the apparatus designed for these experiments is given herewith in Fig. 1 which shows the main parts in relation to each other and drawn to scale. It is driven automatically from an electric motor which is connected with pulley A over the grooved surface of which runs a belt connecting it with the larger pulley P as shown above. At the centre of pulley P is arranged a crank arm C which is connected with the vertical rubbing arm D by means of the crank arm CA which joins at the point E. The upright arm D is fulcrummed at F and thus receives a backwards and forwards movement from the action of the crank arm. At the lower end of arm D is shown K to which is attached a block of wood W clamped into position by screw S which is easily removable when it is necessary to change the abrasive material which is placed over the block at L for the purposes of the test. The fabric to be tested is stretched over a tambour frame such as is employed, for example, in machine embroidery, there being an inner hoop over which the fabric is placed at a uniform and standard tension. Over this is pushed an outer hoop slightly larger in diameter than the inner one so that the fabric is held firmly in position.

This tambour is about 12 in. in diameter and may be noticed in end section at T in Fig. 1. Underneath the tambour is placed an inflated leather ball about 11 in. in diameter which rests between the lower table U and the upper table U1. The ball sits firmly on the lower table but the upper table U1 is cut with a circular opening sufficient to allow the surface of the ball to extend about 0·8 in. above the level of the upper board as shown. The ball is kept inflated at a given pressure, details of which are given hereafter, and the standard pressure selected is accurately registered by the height of a column of mercury shown in the tube at R. Should the mercury fall below the mark, more air is blown into the ball in the usual manner, although in practice it is found that the pressure is maintained fairly regular over a large number of tests. The lever arms have the following dimensions, crank arm C is 2 in. in length, arm CA is 13 in., the distance from F to E is 7 in., whilst the total length of arm D as far as K is 23 in. The block K is 3 in. in length and is about 2·25 in. across, being curved as shown.

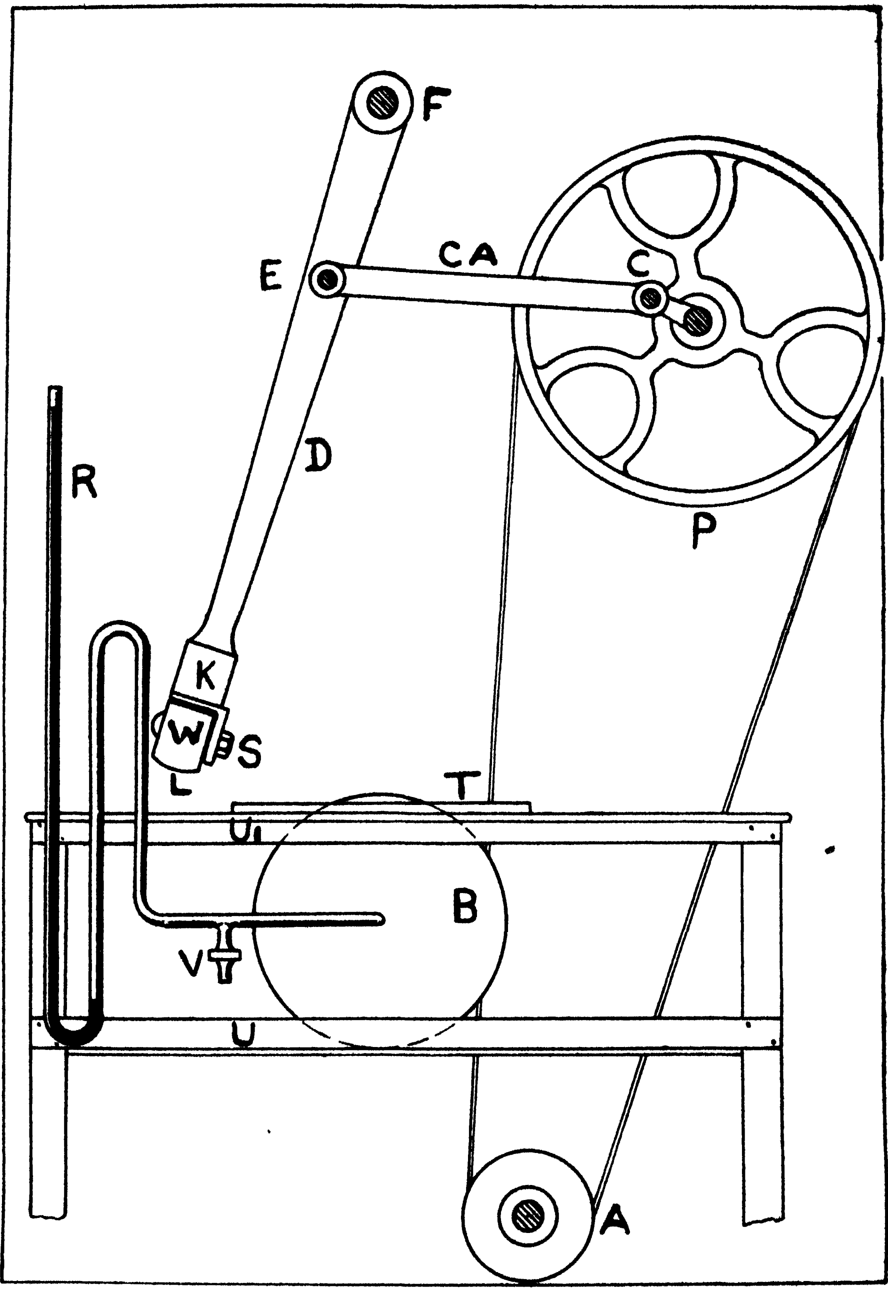

Fig. 1

In fixing the fabric into the tambour frame, a series of weights are attached regularly round the circle, the weights in this case being found suitable at 9·75 ounces. By suspending the same weights for each succeeding test piece, the fabric is offered to the action of the rubbing arm at the same degree of tautness. To make the test the rubbing arm D swings from side to side when the machine is started and the speed of the arm is important. As this method of testing is apt to be protracted there is a temptation to accelerate the arm to secure quicker results, but it is found that beyond a given speed, a disturbing factor makes itself felt in the form of considerable heat generated by friction between the surfaces. After a number of trials it was found that a speed of travel of from 2·2 to 2·5 feet per second, equal to 108 rubs per minute, does not raise the temperature of the rubbing surfaces more than a few degrees. Next to the speed of the arm D, the nature of the rubbing material to be stretched over L is important, for it is necessary to have a fabric firmly woven and possessing little or no surface fibre. After examining a large number of different types of woven fabrics, a standard overcoating cloth weighing 18 ounces per square yard was selected for the purpose. The tambour fitted with the knitted fabric required to be tested is placed in position over the ball B, the tambour being firmly secured at the edges. The ball is of leather and it was thought that to rub the fabric with a woven texture on one side and on a leather base would reconstruct conditions similar to those under which a knitted fabric is worn next to the skin and having a woven fabric on top. In actual practice, however, it was found necessary to rest the test piece of knitted fabric on a length of strong woven serge material to maintain the fabric in position during the test. This fabric is also employed to keep the top of the air ball at a constant height during all tests. To control this the fabric is stretched over the ball until the peak is drawn to the standard height. This is determined by a bar or gauge placed on the table at the side and which is swung over the ball at the commencement of each test. The cloth is stretched so as to have the top of the ball just touching this gauge. The abrading fabric on block W is changed after each test as it alters slightly after abrasion and all tests are thus made under the same conditions. The fabric remains under the rubbing arm until a hole appears; the time of treatment is then recorded. Knowing the number of traverses per minute to be 108, the total number of rubs required to produce a hole are recorded as the test figure. For a machine in constant use, it is an advantage to add a stop motion to bring the apparatus to a standstill automatically when a hole appears. A counter to register the number of rubs can also be fitted for convenience in recording.

A large number of preliminary experiments have been conducted to ascertain the best conditions under which this apparatus may usefully be employed in gauging the wearing power of knitted fabrics. It was found that the nature of the result depended on (1) the material from which the fabric had been made and (2) the degree of pressure of air exerted against the inside of the ball.

Preliminary trials were also necessary to determine the direction in which the fabric should be abraded, in the course of which it was ascertained that results differed according to the following conditions—(*a*) abrading the face of the knitted fabric with the abrading arm travelling in the same direction as the wales or vertical line of stitches; (*b*) travelling across the fabric at right angles to the wales; (*c*) rubbing the back or reverse side of the fabric in the vertical direction; and (*d*) rubbing the reverse or wrong side across the wales at right angles. In the course of those trials it emerged that conditions must be selected to enable the tests to be completed within a reasonable time. Under certain circumstances with the fabric lightly rubbed, it withstood the action of the abrading arm day after day, without much change being observable. It was found that action on the face and in the vertical direction gave in general very protracted tests. It was finally observed that to act on the back of the fabric across the stitches or wales was a method which bore most directly on the largest area of loops and brought a decision within a practicable space of time.

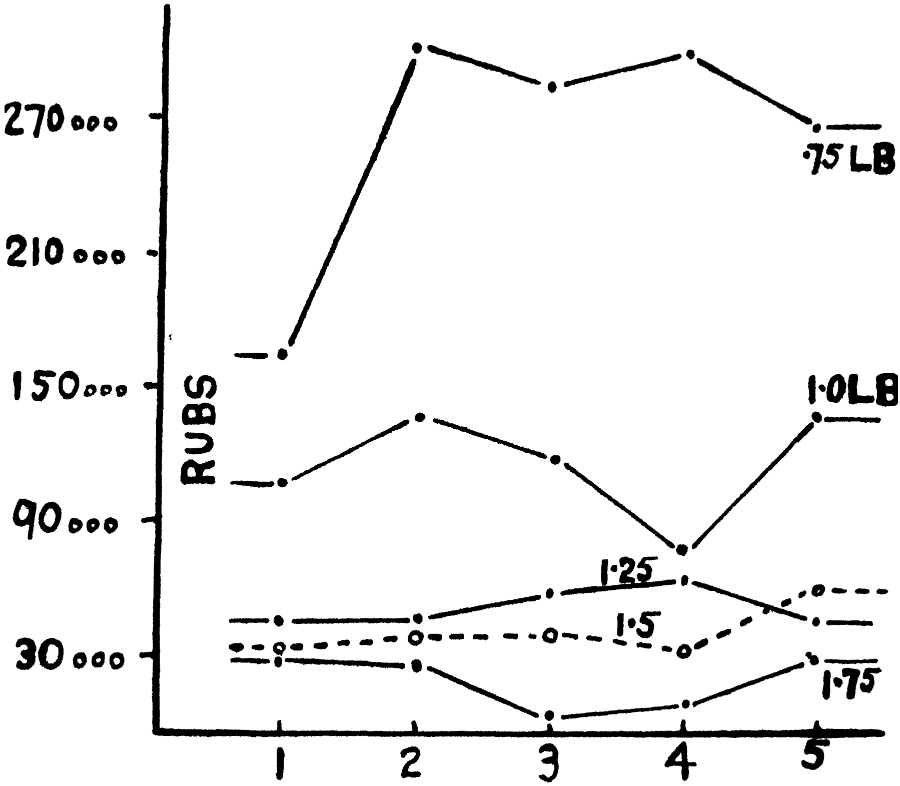

FIG. 2

From preliminary observations it was evident that the conditions require to be altered according to the nature of the material. Woollen fabrics quickly wear into a hole under conditions which cotton would withstand for a prolonged period. To discover the best conditions for making the trials on cotton fabrics, a series of abrasion tests were made on a standard type of plain fabric produced from 20's carded single cotton counts on a spring needle circular frame. This fabric was subjected to a light scouring process and afterwards to calender pressing and had 26 stitches and 34 courses per inch finished. The weight was 4·3 oz. per square yard and the thickness 0·01 in. The thickness was measured on the Wool Industries Research Association thickness tester, at the standard compression of 10 grams. per square centimetre. As previously mentioned the abrading surface consisted of a standard woven overcoating cloth weighing 18 oz. per square yard. Five series were conducted under increasing degrees of air pressure inside the ball varying as follows—

A	...	0·75 lb. per square inch
B	...	1·0 ,, ,,
C	...	1·25 ,, ,,
D	...	1·5 ,, ,,
E	...	1·75 ,, ,,

Five tests were made on each pressure from A to E and Fig. 2 shows a record of the results 1–5.

The general effect of increasing the pressure of the air inside the ball is well defined in these examples; the mean figure for 0·75 lb. being 263,822. This shows a marked reduction as the pressure is increased, the figure at 1·25 lb. being 55,289, and at the highest pressure of 1·75 lb. 20,455. This series of

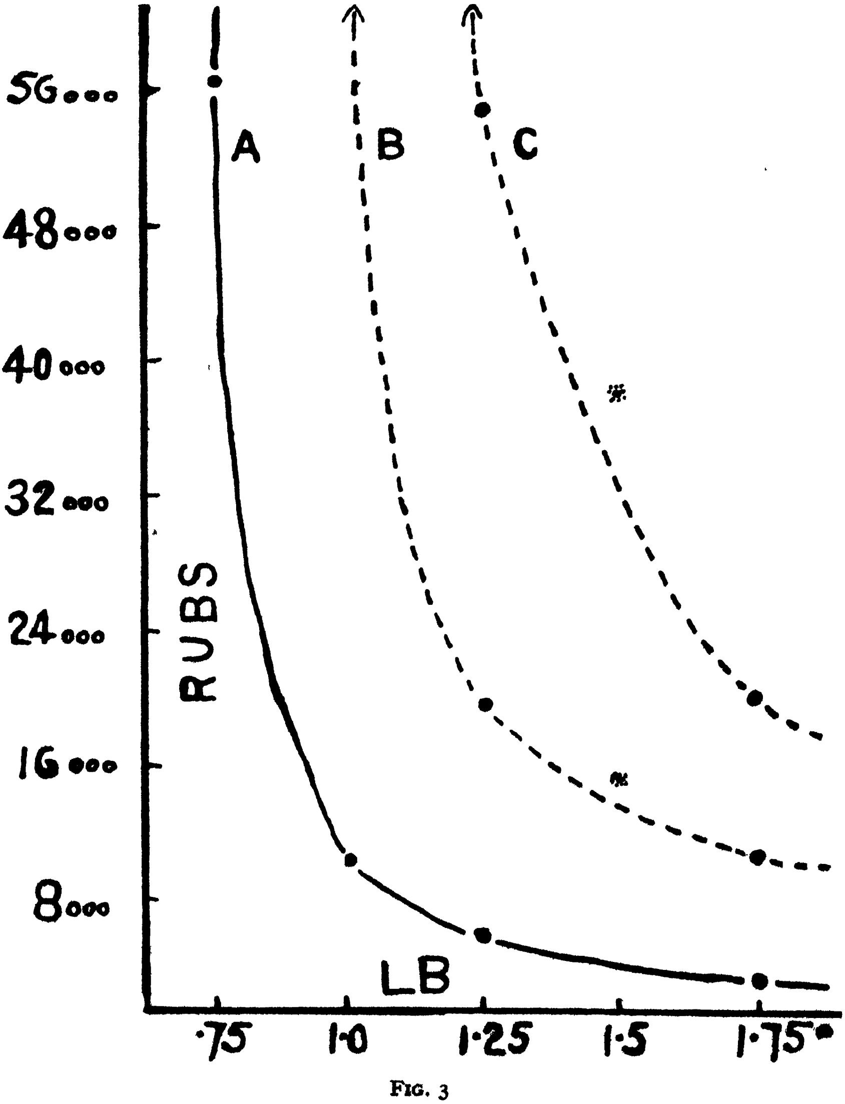

FIG. 3

mean results is shown in the curve C of Fig. 3 where the number of abrasive rubs or beats is given against the various pressures. In deciding on the optimum pressure at which this method should be employed, it is evident that the lowest pressure of 0·75 lb. per square inch is too small to render the test in any way practicable as this requires an average of over 40 hours in which to complete one test. The highest pressure of 1·75 lb. would appear to be a suitable standard to adopt.

A similar series of trials was made on a regular type of plain stitch fabric knitted on a spring needle circular frame from two-fold worsted yarn of 64's botany quality, with 27 stitches per inch and 32 courses per inch, scoured and finished in the usual way. The weight of this was 6.47 ounces per square yard and the thickness ·028 in. As before pressures were taken in four series, ·75, 1·0, 1·25, and 1·75 lb. per square inch and the results of the means of five tests of each are shown in the curve A of Fig. 3.

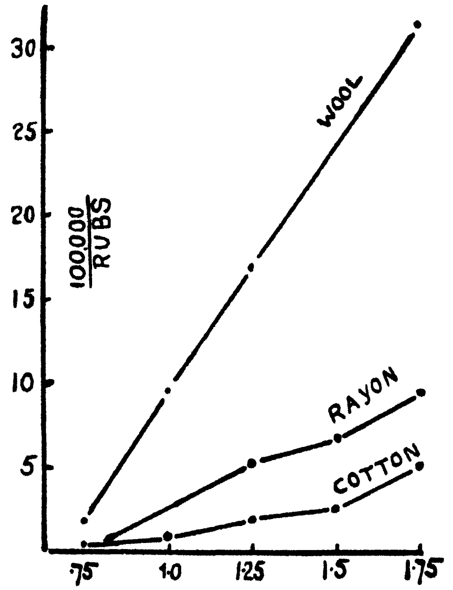

FIG. 4

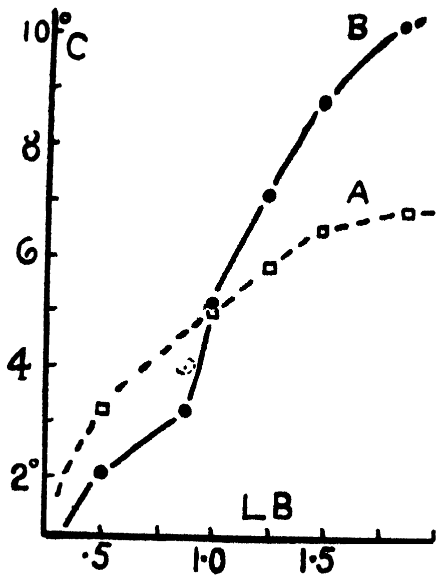

FIG. 6

The mean number of rubs at the lowest pressure ·75 lb. is 56,160 as compared with 263,822 rubs on the plain cotton fabric at the same pressure. At the highest pressure of 1·75 lb. the total for wool fabric is 3,014 as compared with 20,455 rubs on the plain cotton fabric. Again the difference of results between 1 lb. and ·75 lb. is enormous and the highest pressure would appear to give a suitable standard.

A corresponding series of trials was made on a plain stitch, rayon knitted fabric produced on a latch needle circular machine having 12 needles per inch with 450 deniers rayon counts. This fabric weighed 3·82 ozs. per square yard and had a thickness of 0·02 in. The results of these are similarly given in the curve B of Fig. 3, showing the gradual increase in the number of rubs as the pressure is reduced. At the highest pressure of 1.75 lb. the mean number works out at 10,788 as compared with 3,014 rubs for the wool, and 20,455 rubs for the plain cotton. At the lowest pressure the rubbing arm slipped very lightly over the glossy surface of the artificial silk cloth, the number of rubs required to make a hole being just over 330,000 or equivalent to more than 50 hours' action under the abrasive arm.

It is evident that there is some definite connection between the number of rubs required to produce a hole in the fabric and the pressure between the abrasive surfaces; the form of the curves in A, B, and C of Fig. 3 suggest a hyperbola. This indicates that the relation between the reciprocal of the number of rubs and the pressure should be approximately linear. Fig. 4 shows this relation ($10^5 \times$ reciprocal of number of rubs) plotted from the previous results and it will be seen that the curves are as expected, particularly for the wool. The three curves cross the axis of pressure at about 0·7 lb. per sq. in., indicating that below this pressure the amount of wear is negligible. Examination of the machine supports this result, the area of contact of the rubbing surfaces at this pressure being very minute.

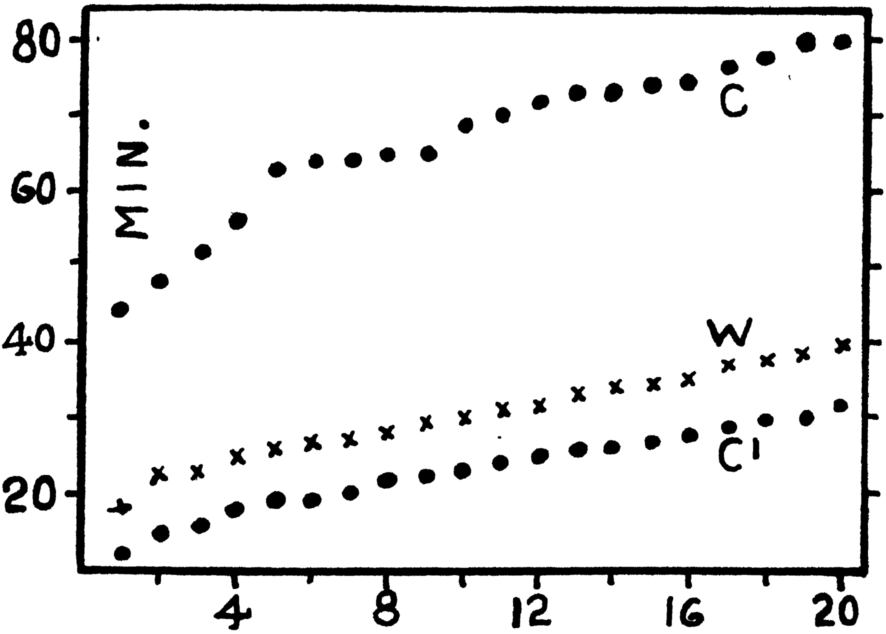

FIG. 5

A few examples are given herewith of the method applied to testing the wearing properties of several types of knitted fabrics. One was made from 2/26's worsted counts of woollen crossbred material worked on the latch needle circular machine having 12 needles per inch in the circumference and with 18 courses per inch. The weight was 5·24 oz. per square yard and two measurements for thickness made on Marsh's apparatus gave 0·058 in. at a pressure of 1 gram. per square centimetre, and 0·036 in. at a pressure of 10 grams. per square centimetre.

The conditions were similar to those already detailed except that the results were recorded in minutes duration of the test as being more convenient, the average number of rubs per minute being 108 as before. The results of 20 such records are given in Fig. 5 where the individual results are plotted in crosses in ascending order against the minutes required to abrade the material into a hole. The range of values indicated by diagram W exhibit the results on the 2/26's wool fabric where the minimum recorded is a 18 minutes' abrasive period rising to a maximum of 40 minutes, in ascending order. Graph C gives a similar series for the 8's cotton knitted fabric worked on the same machine and gauge as the 2/26's wool and with a correct normal finish. The minimum is given as 44 minutes rising in ascending order to 80 minutes. As the thicknesses and texture are approximately equal, these two series may be taken as representative of the results of abrading wool on cotton and the similar action on wool. The cotton fibre is much smoother in surface and the abrading arm slides more easily over it. In contact with the wool the abrading woollen cloth works with a sort of rasping action which rubs a hole in a much shorter time.

The graph marked C1 gives a series of results obtained from the same cotton fabric as in C but where a drastic finishing procedure had injured it, rendering it harsh and reducing its wearing properties. These abrasion trials showed this effect in unmistakable fashion, for they provide a low minimum of 12 minutes ranging to a maximum of 32 minutes in ascending order for 20 test pieces. Comparision of the two sets of results given at C and C1 bear clear evidence of the drastic and damaging effect of a wrong finishing process and shows an interesting way in which the method may be employed in the investigation of fabric faults of this character.

To ascertain the temperature resulting from the abrasive action between the two surfaces, the ball of the apparatus shown in Fig. 1 was inflated to the series of pressures already noted and the temperature measured by pushing the bulb of a thermometer between the two surfaces and registering the increase in temperature thereby produced. Graph A in Fig. 6 shows the individual records of such measurements on the 8's cotton fabric at pressures in the following range—·5 lb. per square inch, ·75 lb., 1·25 lb., 1.5 lb., and 1·75 lb., and the individual points have been connected to give a curve plotted against temperature in centigrade. The temperatures represent the increase from the normal starting temperature as measured between the two surfaces before abrasion was commenced and the curve shows how the heat increased after rubbing for 5 minutes at the various pressures indicated. Particularly in the higher temperatures there is, of course, a certain loss due to the time taken for the thermometer to record. The curve B shows the results of a similar series of observations on the woollen crossbred fabric of 2/26's worsted counts. The contrast between wool-on-cotton and wool-on-wool in this respect is very marked. The temperature increases by just over 3° C. for cotton at graph A for the lowest pressure, rising as shown until there is an increase of nearly 7° at the highest pressure of 1·75 lb. per square inch. In the wool series of graph B, the increase in temperature at the lowest pressure is given by 2° rising rapidly to a maximum of just over 10° at the highest pressure of 1·75 lb. per square inch.

Received 21/9/31

9—THE INFLUENCE OF FIBRE-LENGTH ON THE PROPORTION OF FIBRE-STRENGTH UTILISED IN COTTON YARN

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INTRODUCTION AND SUMMARY

Several different experiments have been carried out concerning the relation between the strength of the cotton fibres and the yarn produced. By these experiments it seems that often the strength of the yarn is only about 10–20% of that of the fibres, and these low values first depend upon irregularities in the count and the twist of the yarn. If specially regular and short pieces of yarn are chosen for experiments in the same way as, for example, Gulati and Turner[2] have done, a considerably higher effect of efficiency is obtained.

In this paper the question of the theoretically probable use of the fibre-strength and chiefly its dependence on the fibre-length will be treated. *Part I* deals with the question of the influence of the fibre-length on the number of fibres that break at the breakage of the yarn if other conditions are equal. All fibres in the cross section of the yarn are not so strongly fastened, that they break. Some of the fibres slip apart. The fibres slipping apart have their ends at or close to the place of breakage. The length of the yarn on both sides of the place of breakage where fibre ends are slipping apart, is herein called *the length of slippage.*

If the *length of slippage* is known, the following formula that shows the relation between the number of broken fibres, the length of slippage and the average length of fibres can be developed.

$$z_k = 100 - \frac{g}{m}\left(100 - \frac{\beta}{2}\right)$$

where z_k = percentage broken fibres to total number of fibres in the cross section.
g = *length of slippage.*
m = average length of fibres in the yarn.
β = percentage number of fibres in the yarn, in length $< g$.

From the experiments of Gulati and Turner this formula points to the *length of slippage* being about 8 mm. in yarn twisted to 27-30 turns per inch.

In *Part II*, examinations have been carried out in order to estimate, under certain assumptions, how the fibre-length influences the fibre-strength utilised in the yarn. On the basis of the results in *Part I* the relation between the breaking-strength of the yarn in % of the single fibre-strength in the cross section of the yarn (*strength of the substance*), the fibre-length and the length of slippage is shown in the following formula.

$$x = 100 - \frac{g}{2m}\left(100 - \frac{\beta}{4}\right)$$

where x = tensile strength of the yarn as a percentage of the total strength of all fibres in the cross section (*strength of the substance*).

The formula seems to apply for yarn not too loose twisted, *i.e.* more than about 20 turns per inch.

THE RELATION BETWEEN THE NUMBER OF FIBRES BREAKING AT THE RUPTURE OF THE YARN, AND THE FIBRE-LENGTH

When a yarn is broken, all fibres in the cross section at the place of breakage do not break, but a greater or smaller number of these, the ends of which are at or near to the place of break, slip apart. It is clear that the shorter the fibres are, the more fibre ends will be within a certain length of the yarn at the place of break if other conditions are equal. How many fibres will be broken is dependent on the strength of the fibres and the friction between them. The friction is highly dependent on the twist of the yarn. A very loose-twisted yarn breaks, when loaded, only by the slipping of the fibres. In a highly-twisted yarn it happens that more than half the number of fibres break, when the yarn is broken. Hereunder is a further consideration of the relation between the fibre-length and the number of fibres breaking at the rupture of the yarn under certain conditions.

Assume that we have a cotton yarn with n fibres in each cross section, and that all fibres have a length of l. Assume further that the yarn has such a twist and friction between the fibres that each fibre has to reach more than 4 mm. beyond either side of the place of break to be held together with such a strength that instead of slipping, it breaks. Thus all fibres having either end within a length of 8 mm. (4 mm. on each side of the place of break), slip apart. This length, here 8 mm., is called herein *the length of slippage*.

If the fibres are evenly distributed along the yarn and n=number of fibres in the *cross section*, there will be, within a length of g mm. (length of slippage), $\frac{n}{l}.g$ fibres slipping apart. Practically yarns are never made of fibres of only one length; but the above-mentioned applies, however, even if the average length of fibres$=l$ mm. and all fibres $\geqslant$ the length of slippage. Suppose that the cotton in question is a mixture of fibres of the lengths l_1, l_2, l_3, l_n. and that the number of fibres of each of these lengths is p_1, p_2, p_3, p_n %. The average fibre-length ($=m$) then will be

$$m = \frac{\Sigma\, p_n l_n}{\Sigma p_n\ (=100)}$$

If the number of fibres in the *cross section* of the yarn still is n, then a certain length L of the yarn contains a total fibre-length$=n$L. Assume further that the total number of fibres in the length L equals N, thus

$$n\mathrm{L} = \sum \frac{p_n}{100}\,\mathrm{N}\cdot l_n = \mathrm{N}\,\frac{\Sigma p_n l_n}{100} = \mathrm{N}\cdot m$$

$$\therefore\ \mathrm{N} = \frac{n\mathrm{L}}{m}$$

The number of fibres of length l_n in the *cross section* of the yarn is then

$$\frac{p_n}{100}\cdot\frac{n\mathrm{L}}{m}\cdot\frac{l_n}{\mathrm{L}} = \frac{p_n l_n n}{100m} \qquad \text{(1)}$$

and in g mm. length of the yarn (length of slippage) there will be $\frac{p_n l_n n}{100}\cdot\frac{g}{l_n}$ fibres of length l_n that slip apart, and of all the different lengths the total number slipping apart is

$$\sum \frac{p_n l_n n}{100\cdot m}\cdot\frac{g}{l_n} = \frac{gn}{m}\cdot\frac{\Sigma p_n}{100} = \frac{gn}{m} \qquad \text{(2)}$$

If the percentage number of fibres that slip apart, in the *cross section*, is called B

$$\text{then } \frac{Bn}{100} = \frac{gn}{m};\ B = \frac{100g}{m}$$

and the percentage of fibres broken

$$z = 100 - \frac{100g}{m} = 100\left(1 - \frac{g}{m}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In Fig. 1 the relation between z and m is graphically shown for different values of g for average fibre-lengths up to 40 mm. Here is to be observed that in reality the length of slippage varies for different fibres in the cross section, and that g consequently corresponds to the average length of slippage for all the fibres. Thus it is to be expected that the fibres on the surface of the yarn slip apart more easily than those in or near to the centre.

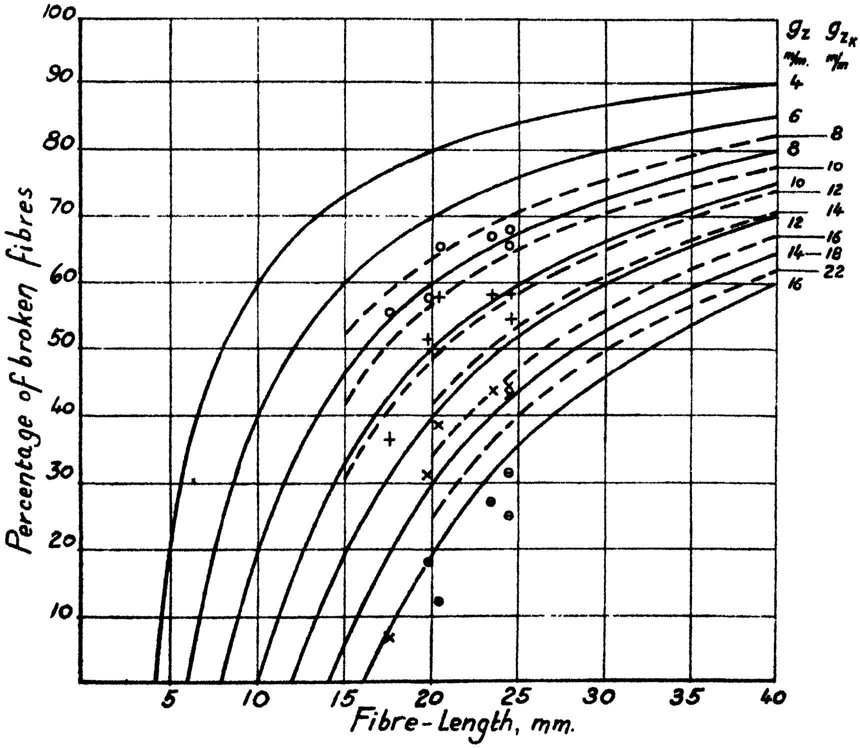

Fig. 1—Relation between the average fibre-length and the percentage of broken fibres in yarn at different length of slippage (=g)

The mean values of the results obtained by Gulati and Turner—

o = yarns with 90 turns per 3 in.
+ = „ 70 „
× = „ 50 „
● = „ 40 „

———————— Calculated without correction for fibres $<g$ [equation (3)]
– – – – – – – – – – Calculated with correction for fibres $<g$ [equation (5)]

From Fig. 1 it appears that the greater the length of slippage, the more rapidly does the number of broken fibres decrease with the fibre-length. Thus at a length of slippage of 8 mm. the number of broken fibres decreases to 2 to 3% per mm., but only at about half this value per mm. decrease in fibre-length between 20 mm. and 30 mm. If the length of slippage is 12 mm. the decrease of fibre-length has nearly twice the influence upon the number of broken fibres as at 8 mm. slippage-length.

Formula (3) however, is only applicable on the assumption that all fibres in the cross section are $\geqslant g$. In common cotton yarn this never occurs. Cotton contains a considerable number of fibres that are shorter than the values of g which are obtained in practice.

Formula (3) has therefore to be corrected in this respect.

Assume that

m=average length of all fibres in the cotton
m_1= „ „ fibres $\geqslant g$ „
m_2= „ „ „ $< g$ „
α=percentage of fibres $\geqslant g$ in the cotton
β= „ „ $< g$ „ „
n=number of fibres in the *cross section* of the yarn
n'=percentage of fibres $\geqslant g$ in the *cross section* of the yarn
z_k= „ broken fibres corrected with respect to the fibres $< g$.

According to (3) $z_k = 100\left(1 - \frac{g}{m_1}\right)\frac{n'}{100}$

but $n' = \frac{\alpha m_1}{m}$ (see equation 1) $\therefore z_k = \frac{\alpha}{m}(m_1 - g)$

but $m = \frac{\alpha m_1 + \beta m_2}{100}$ and also $m_1 = \frac{100\, m - \beta m_2}{\alpha}$

$$\therefore z_k = 100 - \frac{(100-\beta)g + \beta m_2}{m} \qquad \text{(4)}$$

For low values of g, m_2 can be put approximatively similar to $\frac{g}{2}$,

then
$$z_k = 100 - \frac{g}{m}\left(100 - \frac{\beta}{2}\right) \qquad \text{(5)}$$

If z_k is to be calculated according to formula (4) or (5) for different values of g it is necessary to know the percentage of different fibre-lengths contained in the cotton in question. Knowledge of this can be obtained by examination of the cotton, according to the methods of Johannsen or Balls.

Johannsen and Schmid[4] have published examinations of the fibre-length of 28 different samples of American cotton. These kinds of cotton have on the average about 20% fibres in lengths 0–8 mm., about 25% 0–10 mm., about 28% 0–12 mm., about 33% 0–14 mm., about 37% 0–16 mm., and about 45% 0–18 mm. If these values are taken as a basis for the calculation of z_k according to (5), on the supposition that the mean values are independent of the average fibre-length of the cotton, the curves which in Fig. 1 are marked - - - are obtained. As will be seen, these curves lie above the corresponding ones of z. The difference is slight at short lengths of slippage (8 mm. or less), but increases with the length of slippage. Thus at 16 mm. length of slippage, the curve for z_k is about 8–20 units higher than that for z.

What length of slippage is obtained in cotton yarns in practice ? An idea can be obtained by determination of the percentage of fibres that are broken at yarn-breakage. Such determinations have also been carried out for example by Miss Clegg[3] and by Gulati and Turner[2]. Gulati and Turner examined a series of cotton yarns spun from six different cottons in 20, 30, and 40 counts and twisted to 10, 20, 30, 40, 50, 60, 70, 80, and 90 turns per 3 in.

If from Gulati and Turner's results the mean value of the percentage number of the broken fibres, for example, at 90 turns per 3 in. for all three counts from the different cottons (average fibre-length 17·3–24·6 mm.), are calculated, the values dotted in Fig. 1, and marked with circles are obtained. These values nearly coincide with the theoretically calculated line for the length of slippage=8 mm. Similar calculations, carried out for 70 turns per 3 in., give the values in Fig. 1 marked with +. These points are clustered about the curve for 10 mm. length of slippage. The corresponding values for 50 turns are in Fig. 1 marked × and are nearest to the curve for 14–16 mm. length of slippage. These results obtained by direct determinations verify the theoretical calculations and show that the calculations correspond with the practical conditions. From Gulati and Turner's determinations it seems too that at 27–30 turns per inch one can scarcely obtain a shorter length of slippage than about 8 mm., which gives at 20 mm. average fibre-length the highest percentage (63%) of broken fibres in the cross section at the breakage of the yarn. It is to be noticed that the mean lengths of fibres in the cottons can have changed at manufacturing to yarn, and therefore the given values are not exact.

When the twist decreases and the length of slippage increases, the values for yarn from the shortest average fibre-length tend to be lower than those shown by the curves. This may depend upon β here being greater than the mean values used in the calculations. Also it may be pointed out that according to Johannsen and Schmid the values of average fibre-length, obtained by the Balls Sorter are too high and correspond nearest to the average fibre-length of all fibres > 8 mm. If the average fibre-length, mentioned by Gulati and Turner, is determined by the Balls Sorter the values in Fig. 1, calculated from the above-mentioned authors' examinations, would be moved to the left and thus better coincide with the theoretical curves.

THE RELATION BETWEEN THE STRENGTH OF THE YARN, FIBRE-STRENGTH AND THE FIBRE-LENGTH

The relation between the length and the strength of fibres and the strength of yarn spun of those fibres is dependent on many other factors, besides the strength and the length of the fibres and the twist of the yarn. Thus it can be foreseen for example—

(1) That the fibres which break do not all break at the same time.

(2) That the fibres are not ideally distributed along the yarn.

(3) That the length of test-specimens is unknown.

(4) That the fibres are spirally twisted in the yarn, etc.

If leaving these factors out of the question, the strength of the yarn is to be considered dependent only upon the strength and the length of the fibres at a certain twist, the following investigation gives an idea of the relation between the fibre-strength, the fibre-length, and the yarn-strength.

The breaking-strength of the yarn is dependent not only on the number of fibres broken at the breaking-place of the yarn, but the fibres, gliding apart, too, bear a certain part of the load necessary for breaking. As previously mentioned, these fibres can be of such kinds that some of them are $\geqslant g$ and the others $< g$. For those which are $< g$ an average length $= \frac{g}{2}$ approximatively can be assumed, and for those which are $\geqslant g$ an average length $l > g$. Then the yarn can be divided in three parts: one part containing fibres $< g$; a second part containing fibres with an average fibre-length l and with one end within the section g; and finally the third part although containing fibres, length on the average $= l$, with the two ends on either side of the length of slippage g. This is shown schematically in Fig. 2. If the friction is assumed to be directly proportional to the length of slippage, the fibres, of the length l and one end in the section g, will carry a load in average $= \frac{k}{2}$, and the fibres with both the ends within the section g a load in average $= \frac{k}{4}$, where $k =$ the average tensile strength of the fibres. Under these conditions the tensile strength of the yarn is

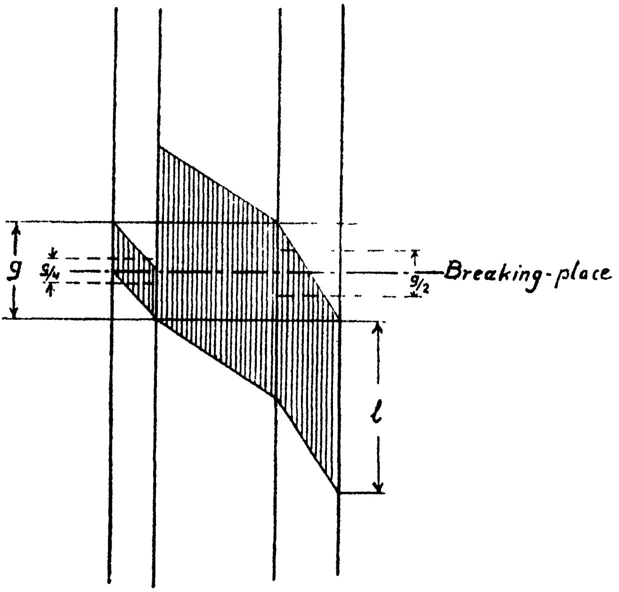

Fig. 2—The yarn at the breaking-place schematically shown

$$x = b_1 k + b_2 \frac{k}{2} + b_3 \frac{k}{4} \quad - - - \quad \ldots\ldots\ldots\ldots (6)$$

where $x =$ tensile strength of the yarn
$b_1 =$ number of breaking fibres in the cross section of the yarn
$b_2 =$,, gliding fibres $\geqslant g$,, ,, ,,
$b_3 =$,, ,, ,, $< g$,, ,, ,,

Obviously the theoretical assumptions for this formula only correspond roughly to the practical conditions.

To get an idea of the value of the formula, the author has calculated the breaking-strengths of yarn, examined by Gulati and Turner. These yarns were 20's, 30's, and 40's made from five different cottons, all yarns with 90, 80, 70, 60, 50, and 40 turns per 3 in. To perform such a calculation it is necessary to know the strength of the fibres, the length of slippage, the number of broken fibres, and the number of fibres shorter than the length of slippage in the cross section at the place of breakage. Gulati and Turner have stated the average fibre-length of the different cottons, the average weight per inch and the fibre-strength in "Technological Reports on Standard Indian Cottons 1930", the report in which the frequency of the different fibre-lengths also is mentioned. At their yarn-examinations, Gulati and Turner have determined the average weight per inch of the fibres too. The values obtained in this way are for most of the cottons considerably higher than those given in the above-mentioned report. Thus the cotton fibres in the yarn seem not to conform to the corresponding qualities of the raw cotton, possibly entirely or partly dependent upon the change into yarn. That is why the average fibre-length, the strength, and the frequency of the fibre-lengths in the raw cotton probably are different from those of the yarn. This gives doubts as to the values of the yarn-strength, calculated according to equation (6), and thus the values obtained cannot be of great importance. The calculation has been carried out and the results are put together in Table I.

Table I—Tensile-strength recorded as a percentage of those calculated for yarns examined by Gulati and Turner

Turns per 3 in.	20's	30's	40's	Average
90	97	95	97	96
80	97	99	89	95
70	94	100	88	94
60	86	87	89	87
50	83	74	79	79
40	82	62	53	69

It is to be pointed out that the tensile-strength of yarns, made from different cottons, shows rather great differences between the calculated and the found strength. Thus the found tensile-strengths of yarns, made from cottons N.14 and Umri Bani, are considerably lower than the calculated ones. Relatively low *calculated* values are also obtained from P.A. 289 F. As to the yarns of N.14 and Umri Bani, stress is to be laid upon the fact that the number of fibres in the cross section of the yarn, mentioned by Gulati and Turner, is considerably lower than those values obtained by calculating them from the weights of the fibres and the counts of the yarns, given by the authors, though there are no considerable deviations for the yarn of P.A. 289 F.

Knowledge of the true number of fibres in the cross section of the yarn at the breaking-place is of great importance for an exact calculation of the tensile strength. Also at the short lengths of yarn (3 in.), as Gulati and Turner have used for investigation, variations in this respect can be found. Probably the place of breakage contains slightly fewer fibres than those calculated as an average for all the length (3 in.), and this would explain why the calculated values of the tensile-strength may be too high. This may be the reason or one of the reasons, why the finest yarn (40's) has given higher calculated values in proportion to the found ones than the thick yarns. For the 40's yarn a discrepancy of only five fibres in the cross section, for example, causes a considerable error in the result.

The mean values of the calculated and the found tensile-strengths show a tolerably good conformity, when the number of twists is at least 70 turns per 3 in. When the twist decreases to below 70 turns per 3 in., the obtained values of the breaking-strength decrease obviously more quickly than the calculated ones.

Possibly also at loose twist other matters than those represented in the formula may have an influence. Probably it is the influence of the surface. In the formula there is supposed a certain homogenity in the yarn which exists only to a certain extent in reality. The fibres on the surface are thus considerably more free than the fibres in the inside. When the twist is decreasing, this surface layer grows thicker and thus its influence becomes more predominant.

By use of the precedent relations the following equation (7) can be obtained for the connection between the fibre-strength, length of slippage, length of the fibre, and strength of the yarn.

We have (see equation 6) $x = b_1 k + b_2\frac{k}{2} + b_3\frac{k}{4}$

hence
$$x = k(n - b_2 - b_3) + b_2\frac{k}{2} + b_3\frac{k}{4}$$
$$= kn - b_2\frac{k}{2} - b_3\frac{3k}{4}$$

But we have by (2) $b_2 = \frac{agn}{100m}$ and by (1) $b^3 = \frac{\beta m_2 n}{100m}$

hence
$$x = kn - \frac{agn}{100m}\cdot\frac{k}{2} - \frac{\beta m_2 n}{100m}\cdot\frac{3k}{4}$$
$$= kn\left(1 - \frac{ag}{2\cdot 100m} - \frac{3\beta m_2}{4\cdot 100m}\right)$$

and thus x in % of the strength of the substance
$$= 100 - \frac{ag}{2m} - \frac{3\beta m_2}{4m}$$

and if $m_2 = \frac{g}{2}$ then
$$x \text{ in } \% = 100 - \frac{g}{2m}\left(100 - \frac{\beta}{4}\right) \quad \ldots\ldots (7)$$

To be able to calculate the strength of a completely even yarn it is necessary to know the number of fibres in the cross-section, their tensile-strength, the average fibre-length, the average length of fibres shorter than the length of slippage, the percentage of fibres $\gg g$ and the length of slippage; g depending on a direct measure of the twist.

Out of (7) the curves, representing the relation between x in %, g and m, given in Fig. 3, are obtained which have been calculated with acceptance of the values of β, obtained by Johannsen and Schmid. These curves, being uniform with the curves in Fig. 1, show how the average fibre-length at different lengths of slippage or at different twists influences the degree to which the fibre-strength can be utilised in cotton yarn, which is the principal purpose of this investigation. From these curves it appears that it is not possible to render useful more than 80% of the strength of the substance at an average fibre-length of 20 mm. and at a twist of 27–30 turns per inch of the yarn. Here the length of slippage will be about 8 mm. At a length of slippage of 12 mm. only 70% of the fibre strength is used at 20 mm. average fibre-length.

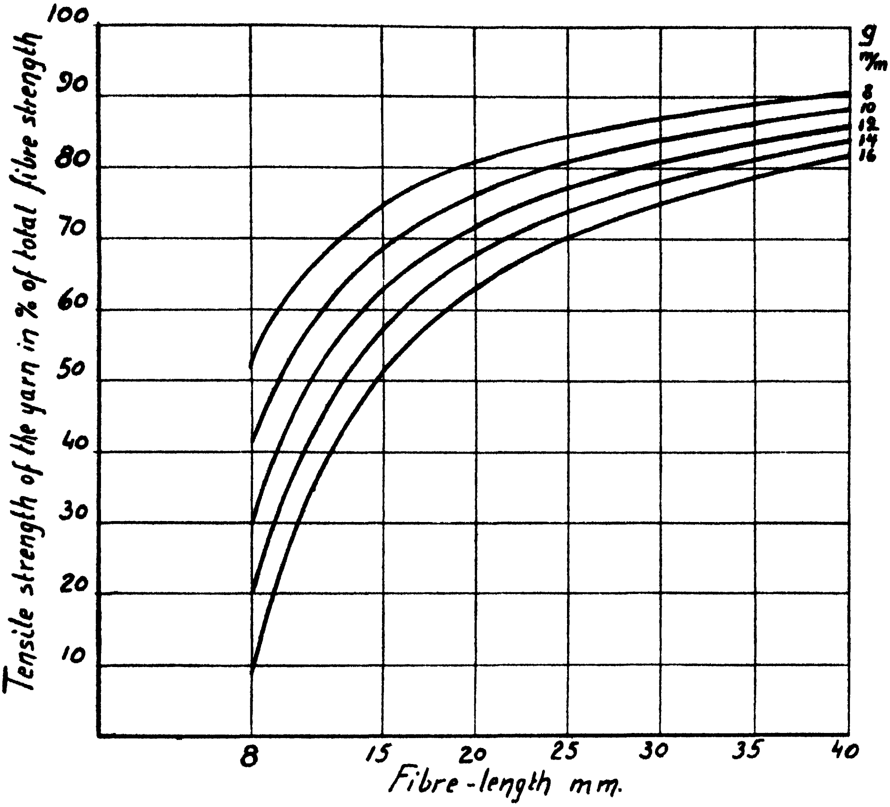

Fig 3—Tensile strength of the yarn in per cent. of the strength of the substance (= total fibre-strength) at different average lengths of fibres and at different lengths of slippage (= g) according to the equation (7)

The curves show also the well-known fact that the shorter the mean fibre-length, the greater is the influence of the twist (i.e. the length of slippage) upon the strength of the yarn.

The theoretical examination carried out here is meant to bring to a sound basis the question of the relation between the length and strength of the fibres and that of the yarn, and is illustrated by the above-mentioned applications to practical results, using the investigations by Gulati and Turner.

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10—A NOTE ON THE WAX CONTENT OF INDIAN COTTONS WITH SPECIAL REFERENCE TO THEIR FEEL

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SUMMARY

The wax occurring on cotton fibre, though present in extremely small quantities, plays an important part in the spinning, wetting, dyeing, and scouring processes. It has, besides, a direct bearing on its feel as estimated by a grader. The wax content of 11 Indian and 1 non-Indian cottons has been determined, principally with a view to correlating it with its degree of silkiness or harshness. The results obtained show that the wax content of Indian cottons may range from 0·229% to 0·468%, that the exotic varieties grown in India have, on the whole, a higher wax content than the indigenous types and that the *subjective* estimates of the feel of a cotton, made by different graders are likely to disagree among themselves and with the results of the wax determination tests. Comparing the reports of the graders with the results of the tests a tentative scale is suggested in which the degree of silkiness of a cotton is expressed in terms of its wax content.

I—INTRODUCTION

In comparison with the other constituents of cotton fibre the amount of wax on it is extremely small, being of the order of 0·2 to 0·6%. Nevertheless, it plays an exceedingly important part in many of the processes to which cotton is subjected in the manufacture of fabrics. Thus, according to Johnson[1] the wax becomes plastic above some fairly definite working temperature and acts as a lubricant while the resulting pliability of the fibres helps the cotton to process more easily. This view is confirmed by an experiment performed by Knecht[2] who carried out spinning tests on an ordinary and a de-waxed sample of the same cotton. He found that whereas the ordinary sample could be spun up to 48's counts, it was difficult to spin finer than 26's counts from the de-waxed sample which, besides, gave excessive waste in the blowroom, required readjustment of rollers in the draw-frame and produced a large amount of fluff and clearer waste in the fly-frames. The roving obtained from the de-waxed sample was irregular and the yarns spun from it were 26·9% weaker in 26's and 24·5 % weaker in 48's than those obtained from the ordinary sample. Thus, although the amount of natural wax associated with cotton rarely exceeds 0·6% its complete or even partial elimination may adversely affect its spinning performance in a very marked manner. No less important is the part played by the cotton wax in the dyeing, wetting, and scouring processes. According to Brown[3] the presence of wax makes cotton somewhat impervious to water and for that reason it is necessary to remove it from absorbent cotton and cotton that is to be dyed. W. L. Balls[4] is of the opinion that until the wax which is present on the seed coat and which is very similar to that on the lint is removed by the initial swelling of the seed, the absorption of water is difficult. The part played by wax in the scouring process is so important that Fargher and Higginbotham[5] recommend the determination of the wax content of a sample as a means for following the scouring efficiency, especially when sodium carbonate or lime are used as the reagents.

The waxy material occurring on cotton fibre is of a highly complex character. Its composition has been studied in great detail by Fargher[6] and his associates, who have found it to consist of a large number of solid alcohols, acids, esters, hydrocarbons, and resins. Some of these substances are readily soluble in such common organic solvents as ether, light petroleum, and benzene, while others are sparingly soluble. The extraction of the latter proceeds at a very low rate and presents formidable practical difficulties. It was probably due to these reasons that Knecht[7] and his co-workers put forward the view that raw cotton contains much more waxy material than can be extracted in the ordinary way, that bulk of this material was probably hidden between the concentric sheaths of the hair and that it could only be obtained when the barriers were broken down either by mechanical means or by destruction of the cellulose structure by an acid of suitable strength. This view, however, is not shared by Fargher[8] and his co-workers whose experiments led them to believe that the total waxy material including that present in the form of insoluble soaps exceeds that estimated by the usual methods by 0·1 to 0·2% only, which is very much less than the figure suggested by Knecht[9]. They hold that the extraction of waxy and resinous material may continue for a long period, not because of any wax lying hidden in the interior of the fibre but because of the complexity of the substances collectively designated cotton wax and the lack of complete change of solvents in contact with this material. In order to settle this point once and for all, they adopted the suggestion thrown out by Knecht of destroying the structure of the fibre prior to the determination of its wax content, and found that the effect of such treatment is considerably less than that indicated by Knecht, the extracts being due not to the material which could not otherwise be removed but to the more ready extraction of the substances which are ordinarily eliminated very slowly. They finally came to the conclusion that "there is no evidence of the relatively large amount of wax and resin which are protected from the attack by their position within the hair".

II—OBJECTS OF THE EXPERIMENT

Besides the part played by the wax in the spinning, wetting, dyeing, and scouring processes it has a direct bearing on the feel of a cotton as estimated by a grader. It is a well-known fact that in valuing a cotton a grader not only estimates its class and grade and the length, strength, and regularity of its staple but also the degree of its silkiness or roughness. Not only the main classifications of the world's cottons such as Sea Island, Egyptian, American, East Indian, etc., but also the various styles falling under each classification differ in respect of their feel to a greater or less extent. The Indian cottons especially offer a fertile field of investigation for problems relating to the nature and properties of wax associated with cotton fibre as a large number of botanical varieties, indigenous as well as exotic, are grown under very diverse conditions of soil and climate in different parts of India. It was felt, therefore, that a beginning should be made by a determination of the wax content of the more important trade descriptions of Indian cottons and a comparison of the values thus obtained with an expert grader's estimation of their feel. Such an investigation should serve three useful purposes—(1) it should show the extent of variation in the wax content of Indian cottons, (2) it should bring out the influence of heredity on the amount of wax occurring on cotton fibre, and finally (3) it should help in establishing a relationship between the feel of a cotton and its wax content. In order to cover as wide a range in feel as possible, cottons varying from very silky to rough were selected; their trade descriptions will be found in column 2 of Table I.

Table I

Store No	Name of Cotton	Botanical variety	Wax content %	First Grader	Second Grader	Third Grader
1793	Kampala...	—	0·544	Very silky	Very silky	Very silky
1902	Punjab-American	*G. Hirsutum*	0·468	Midway	Silky ...	Slightly silky
—	Cocanada	*G. Obtusifolium Cocanada* (Gammie) and *G. Indicum* (Yerrapatti)	0·465	—	Silky ...	Midway
1794	Navsari ...	*G. Herbaceum* (Linn.) ...	0·457	Silky ...	Silky ...	Very silky
1795	Palej (Broach)	*G. Herbaceum* (Linn.) ...	0·405	Slightly silky	Midway inclining to silk	Slightly silky
1796	Dholleras	*G. Herbaceum*	0·387	Roughish	Midway inclining to silk	Midway
1901	Punjab-Desi	Mixture of— 1 *Indicum*, 2 *Indicum Mollisoni*, 3 *Roseum* etc.	0·385	Midway	Slight rough	Roughish
1797	Kumpta	*G. Herbaceum*	0·359	Roughish	Midway inclining to silk	Midway
1903	Banosa ... (Berar)	Mixture of varieties of *G. Neglectum*	0·330	Midway	Slight rough ...	Midway
1911	Sind-Desi	As for Punjab-Desi ...	0·274	Roughish	Rough ...	Roughish
1904	Hathras (U P.)	As for Punjab-Desi ...	0·261	Silky ..	Slight rough	Roughish
—	Sind Woolly	—	0·229	—	Rough	Roughish

III—METHOD

The method employed in the determination of the waxy material was as follows—

The cotton was well cleaned by hand and its moisture content was determined by heating in a small oven. About 2·5 gms. of this clean cotton of known moisture content was placed in a "Soxhlet's apparatus" and the wax extracted with hot benzene for 4 hours. The benzene was then filtered hot and distilled. The residual material in the distilling flask was transferred to a tared weighing bottle by washing the last trace with hot benzene. The weighing bottle was kept in an oven at 90° C. for about half an hour to remove benzene completely and was subsequently heated at 100° C. till its weight became constant. The increase in the weight of the bottle gave the wax content of the sample. This was corrected for the moisture present in it so as to obtain the value on the dry weight of cotton.

It will be seen that the wax content of cotton has been determined by the direct method of extracting it with hot benzene in a "Soxhlet's fat extraction apparatus". Although ether is generally considered to be the best solvent for cotton waxes, it was found impracticable for our purpose owing to the high temperature prevailing in Bombay, which occasionally approaches the boiling point of ether. Moreover, some experiments performed at the Laboratory in 1924-25 showed that the extraction of wax from Indian cottons with benzene was as efficient as that with ether. This is confirmed by the results obtained by Clifford, Higginbotham, and Fargher[10] who found that for an American cotton the amount extracted with hot benzene was very nearly the same as with ether.

Since a grader's estimation of the feel of a cotton is a purely subjective process and is thus liable to errors of personal judgment, it was felt that these errors would be reduced and greater coherence achieved if the cottons were examined by more than one grader. Accordingly small samples of these cottons were sent to three expert graders who were asked to express their opinions regarding their feel in terms of the standards adopted by them in their daily practice.

IV—RESULTS

The results of wax determination together with the reports furnished by the three graders are given above in Table I.

V—DISCUSSION

It will be seen in the first place that the wax contents of the samples of Indian cottons examined in the course of this investigation varied from 0·468 to 0·229%. The two cottons at the extreme ends of the range are Punjab-American and Sind Woolly, the former containing a little over twice as much wax as the latter; while the other cottons occupy intermediate positions. The one sample of non-Indian cotton included in these tests for purposes of comparison and because of its increasing use by the Indian Mills was found to contain 16% more wax than even the Punjab-American.

A determination of the wax content of some well-known types was made by Lecomber and Probert,[11] from whose results the following table is taken for purposes of comparison.

Table II

Type	Range (%)	Mean (%)	Remarks
American	0·35—0·51	0·435	
Egyptian	0·35—0·43	0·39	Less than American
Sea Island	—	0·52	
South American	0·29—0·54	0·41	Very variable
Indian	0·30—0·42	0·34	

It will be seen that the range of wax content of Indian cottons given by the present experiments is considerably greater than that indicated by Lecomber and Probert. Out of the 11 Indian cottons tested no less than six fall outside their range; the wax content of three samples exceeds 0·42, while that of an equal number is less than 0·30. On the basis of their results they suggested the determination of percentage of wax as a means of differentiation between the American and the Egyptian cottons on the one hand and the Indian cottons on the other. In view of the fact that many of the Indian varieties are shown by the present investigation to contain as much wax as the American and the Egyptian types, it is entirely doubtful if this suggestion can be profitably employed except for the very short stapled and coarse varieties for which surer means of differentiation based upon the other fibre-properties are available.

It will next be seen that the wax content of the exotic varieties falling under the botanical classification of *G. Hirsutum* and *G. Herbaceum* is as a rule higher than that of the indigenous types which are classed under *G. Neglectum, G. Indicum,* etc. The only two exceptions to this rule are (1) Cocanada (*G. Obtusifolium* and *G. Indicum*) which contains a high percentage of wax and (2) Kumpta which in spite of its *G. Herbaceum* origin comes rather low down in the scale. We know from the work of Geake[18] that not only is the phosphorus content of Egyptian cottons much higher than that of American but a sample of cotton grown from Egyptian seed in Arizona retained its characteristic high phosphorus content. In another case, however, the influence of environment was noticed; the phosphorus content of a sample of Mitafifi cotton grown in Peru was found to be 0·075% as against 0·105% for the same cotton grown in Egypt. Thus, the phosphorus content of cotton is probably an inherited character influenced in some cases by environment. On looking closely into the values of wax content given in Table I we observe a parallel case. The exotic varieties whose seed was originally imported from America, have, after years of acclimatisation, retained a high wax content as compared with most indigenous types. Furthermore, the influence of environment will be seen in one case—Kumpta —for which the wax content is even less than that of Punjab-Desi—a pure Indian type. It is highly probable, therefore, that like phosphorus content the wax content of a cotton is also an inherited character though under certain conditions it may be influenced by environment.

Turning now to a comparison of the wax content with the graders' estimates, we find that all of them agreed in designating Kampala as "very silky" and Sind-Desi and Sind Woolly as "rough" or "roughish". There, however, the common agreement stops, though in several other cases, two out of the three graders have expressed a similar opinion regarding the feel of a sample. As against these cases of complete or partial agreement, there are several others in which the graders' estimates are strongly at variance with one another. For instance, while one grader inclines to the view that the sample of Punjab-American cotton is "mid-way", it is "silky" according to the second grader and "slightly silky" in the opinion of the third. Similarly while one grader estimates the Hathras cotton as "silky" the other two regard it "slight rough" or "roughish": Other such instances of disagreement will be forthcoming from a study of Table I. They all throw into prominent relief the fact that no matter how experienced a grader may be his estimate of the feel of a cotton, based upon a hand-and-eye examination, is liable to errors of personal judgment, and that to attain uniformity in standards of feel for purposes of comparison, it is necessary to evolve an objective method as in the case of other fibre-properties and establish a graded scale between the feel and the wax content of cotton.

Let us now examine the individual reports of the graders from this point of view. On doing so we find that report of the second grader agrees more closely with the results of wax determination than either of the other two reports. There are only two cottons, viz. Kumpta and Hathras, for which his estimate is at variance with the results of the tests. When we remember that the determination of wax content of these samples took several days while the grader's valuation was completed probably within half an hour, the observed agreement, notwithstanding the two cases just mentioned, is remarkably good and a tribute to his powers of judgment. The reports of the other two graders do not accord so well with the results of the tests. For instance, the first grader estimated Hathras cotton as "silky" and Dholleras as "roughish" although the former contains 32% less wax than the latter and was set down as "roughish" by the other two graders. Similarly, the third grader assigned a higher place to Navsari than to Punjab-American or Cocanada, but the results of wax determination point in the opposite direction. Taking the greatest common measure of agreement between the graders' reports on the one hand and the results of the present series of tests on the other, we suggest the following scale for expressing the degree of silkiness of a cotton in terms of its wax content. The scale could be further sub-divided but we are inclined to think that for practical purposes a broad classification is better than an elaborate one.

	Wax content (%)
Very silky	above 0·500
Silky	0·425—0·500
Slightly silky (midway inclined to silk) ...	0·350—0·425
Roughish	0·300—0·350
Rough	below 0·300

VI—ACKNOWLEDGMENTS

Our thanks are due to Mr. R. G. Saraiya for his kindness not only in suggesting the problem but also for providing the samples of cotton. Our thanks are also due to the three graders (whose names are left out for obvious reasons) for their kindly examining the samples and furnishing us with their reports.

Dated the 7th December 1933

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CORRIGENDUM

6—"A PHOTOMETER OF SPECIAL APPLICATION TO ROUTINE TEXTILE MEASUREMENTS"

By R. E. V. Hampson, D.Sc, A.I.C., A.M.I.Chem.E.
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The component values referred to in line 31, page T120 of the above article were accidentally omitted from Fig. 7 (page T119). They are printed below.

Fig. 7 List of Components

R1, R2 = 10,000ω
R3 = 50,000ω
R4 = 200ω
R5 = 80,000ω
R6, R7 = 40,000ω
R8, R10 = 30,000ω
R9 = 1000ω

C1, C2, C3 = 1 mfd
C4 to C11 = 2 mfd
C9 = ·203 mfd
C8 ·01 mfd
C10 ·006 mfd

L F T 1 = Parafeed 6:1
L T 2 = A F 3
L.F.C 2 = ·46H

V1 = AC2/HL
V2 = AC/S2
V3 = AC/P

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11—A TACTILE COMPARISON OF THE CLOTH QUALITIES OF CONTINENTAL AND NOBLE COMBED MATERIALS

By Henry Binns, F.T.I.

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INTRODUCTION

In a previous paper[*] some of the results suggested that a further series of tests on the "handle" of cloths by the sense of Touch was desirable. Information as to the stability of the individual judgments, the magnitude of any fluctuations recorded, and the influence of touch would seem to be valuable and it would be helpful to ascertain what effect ill-health, worry, or other conditions had upon sound touch judgment. Such records would appear to have definite educational value.

The Samples Employed

The ranges of samples used were those designated R4, R5, and R6 in the previous paper where full details of the cloths are given (pp. T90 and T95) and this ensured results strictly comparable with those already recorded. Each sample was weighed and the average thickness (20 tests) was recorded by means of an Ashcroft thickness gauge. These are given in column 6 of Table I.

The Judges

These consisted of the two following groups—

(*a*) 22 Manufacturers and buyers of Botany dress goods similar to those used for the tests. Each had had a wide experience and held a responsible position in the trade.

(*b*) 6 Boys (15-18 years of age). One had previously matriculated but continued his studies. Two were intellectually inclined and the other three were more skilled in the direction of handwork at which one was "almost excellent" and the last "distinctly poor".

(*c*) The Experimenter himself.

The Instructions Given

To secure an adequate basis for the measurement of fluctuation it was decided to request each judge to grade each range five times by the sense of Touch alone, placing the samples in the order of his own preference. After each grading, which was recorded by the experimenter, the cloths were mixed by the experimenter before regrading. Every precaution was taken to ensure that not even a casual glance at the cloths was secured and that the influence of "suggestion" (see page T95, previous paper), was entirely absent.

Methods of Calculation

The methods previously employed (p. T91) were again used and the probable errors for the ranges in this investigation were R4 and R5 ±·18, R6 ±·20.

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[*] Psychological Investigations of the Influence of the various methods of manufacturing Worsted yarns on single and two-fold twist-warp cloths—(*a*) Clear finished, (*b*) Milled finished. H. Binns. *J.T.I.*, 1934, **25**, T89–T105.

COMPARISON OF THE GRADINGS BY "FULL"* JUDGMENT WITH THOSE BY "TOUCH" ALONE

Table I—Range R4, Milled Finish

Cloth	Combing	Drawing	Spinning	Weight oz. drms.	Thickness inches	Full Judgment 50 Jdgs.	Touch 22 Adults	Touch 6 Boys	Experimenter
R (B)	Noble	Cone	Cap	4·8½ (1·5)	·0270 (2)	100 (1)	77 (3)	6 (4·5)	100 (1)
T (B)	Noble	Cone	Ring	4·7 (4)	·0266 (4)	82 (2)	92 (2)	100 (1)	95 (2)
U (B)	French	French	Mule	4·5 (6)	·0251 (6)	58 (3)	100 (1)	50 (2)	0 (6)
V (B)	Noble	French	Cap	4·6½ (5)	·0257 (5)	35 (4)	46 (4)	6 (4·5)	10 (5)
W(B)	French	French	Cap	4·8 (3)	·0267 (3)	5 (5)	0 (6)	0 (6)	15 (4)
X	French(B)	French	Cap	4·8½ (1·5)	·0271 (1)	0 (6)	8 (5)	14 (3)	85 (3)

(B) = When backwashed.

The correlation co-efficients of agreement (or disagreement) are given in Table I (*a*).

Table I (a)—R4 Milled Finish

	Weight	Thickness	Full	Touch Adults	Touch Boys	Experimenter	Average
Weight	—	1·00	−·13	−·65	−·46	·82	·12
Thickness ...	1·00	—	−·26	−·65	−·46	·73	·07
Full Judgment...	−·13	−·26	—	·73	·29	·53	·23
Touch (Adults)...	−·65	−·65	·73	—	·73	·00	·03
(Boys) ...	−·46	−·46	·29	·73	—	·16	·05
Experimenter ...	·82	·73	·53	·00	·16	—	·45
				Average	...	... ...	·16

Weight and Thickness

When the samples were prepared all of them were laid full out, flat, upon each other and then the whole lay was cut at one time on a 36-in. gimping machine. The differences in area between one cloth and another must therefore have been exceedingly small and yet there is a variation in weight of 3½ drams.

Group Agreements

The most striking feature of Table I (*a*) is the agreement between the experimenter and weight +·82: and with thickness +·73, and with the full judgments +·53. At the same time there is no agreement with Touch (Adults) at +·00. This points definitely to judgment being recorded by weight and thickness. This may be due to the fact that the writer's experience was mainly on Yorkshire union shirtings, which are relatively weighty and thick and are of a lofty milled finish—all characteristics of this range (R4) of Botany cloths. The other groups definitely reverse this preference, the Touch (Adults) group liking the lighter weights—and also, of course, the thinner cloths. Another point of interest is that the Full Judgment and the Touch (Adults) agree at +·73, suggesting that Touch is the dominant factor in the Full Judgment. As the Touch (Boys) agree with Touch (Adults) at +·73 some natural (as against trained) feature of touch is indicated. It will be noted that the weight and thickness factors are in agreement at 1·00.

Tables II and II (*a*) record similar results for Range R5.

Table II—Range R5, Clear Finish

Cloth	Combing	Drawing	Spinning	Weight oz. drams.	Thickness inches	Full Judgment	Touch Adults	Touch Boys	Experimenter
R (B)	Noble	Cone	Cap	4·4 (1·5)	·0225 (1)	100 (1)	100 (1·5)	90 (2)	100 (1)
T (B)	Noble	Cone	Ring	4·4 (1·5)	·0221 (4)	66 (2)	74 (3)	100 (1)	76 (2)
U (B)	French	French	Mule	4·1 (6)	·0220 (6)	64 (3)	100 (1·5)	67 (3)	0 (6)
V (B)	Noble	French	Cap	4·2 (5)	·0225 (2)	8 (5)	47 (5)	32 (4)	21 (5)
W(B)	French	French	Cap	4·3 (4)	·0220 (5)	24 (4)	58 (4)	26 (5)	43 (4)
X	French(B)	French	Cap	4·3½ (3)	·0223 (3)	0 (6)	0 (6)	0 (6)	57 (3)

(B) = When backwashed

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* See previous paper, Table IV, p. T95.

Table II(a)—R5 Clear Finish

	Weight	Thickness	Full	Touch Adults	Touch Boys	Experimenter	Average
Weight ...	—	·64	·64	·41	·41	1·00	·62
Thickness ...	·64	—	·00	−·13	·00	·73	·25
Full Judgment	·64	·00	—	·95	·89	·73	·64
Touch Adults	·41	−·13	·95	—	·73	·41	·59
Boys ...	·41	·00	·89	·73	—	·29	·46
Experimenter...	1·00	·73	·73	·41	·29	—	·63
					Average		·53

Weight and Thickness

Though not so pronounced as in the milled range, the agreement between weight and thickness is +·64. All groups are influenced by weight and especially the experimenter whose decision is absolutely agreed at +1·00. On thickness the experimenter is again influenced to the extent of +·73 yet he can honestly say that in all judgments the general feeling of quality was the uppermost in his mind. There is no denying the fact that weight and thickness are significant.

Group Agreements

The Full Judgment is practically agreed with the Touch (Adults) and (Boys) and the Experimenter, rather suggesting that a natural and untrained touch, biassed by weight but not by thickness, is at the base of Full Judgment. In the milled range the final average of +·16 shows that opinions are pretty nearly balanced; some persons decide in one direction, others in the opposite. But in this clear range, all are fairly agreed if the thickness factor be excepted. For training purposes, therefore, the clear finish is much more suitable for beginners and the milled for advanced students.

In the following tables the third range, R6 (see previous paper p. T95), is recorded.

Table III—R6 Mid. Finish

Cloth	Combing	Drawing	Spinning	Weight oz. drams.	Thickness inches	Suggestion	Touch Adults	Touch Boys	Experimenter
R	(B) Noble	Cone	Cap	4·10½ (1·5)	·0272 (1)	100 (1)	100 (1)	41 (3·5)	78 (2)
S	(B) Noble	Cone	Cap	4·10½ (1·5)	·0267 (2)	0 (5)	71 (3)	55 (2)	100 (1)
V	(B) Noble	French	Cap	4·9 (5)	·0262 (4)	4 (4)	0 (5)	0 (5)	60 (4)
W	(B) French	French	Cap	4·10 (3·5)	·0254 (5)	15 (3)	88 (2)	100 (1)	0 (5)
X	French(B)	French	Cap	4·10 (3·5)	·0263 (3)	72 (2)	30 (4)	41 (3·5)	61 (3)

(B) = When backwashed

Table III(a)—R6 Mid. Finish

	Weight	Thickness	Full	Touch Adults	Touch Boys	Experimenter	Average
Weight	—	·75	·27	·75	·62	·75	·63
Thickness ...	·75	—	·46	·46	·00	·94	·52
Suggestion ...	·27	·46	—	·46	−·48	·00	·33
Touch (Adults)...	·75	·46	·46	—	·62	·00	·46
(Boys) ...	·62	·00	−·48	·62	—	−·48	·06
Experimenter ...	·75	·94	·00	·00	−·48	—	·20
			Average ...	...	...	...	·37

This range was originally employed in connection with the Personal Suggestion tests and must be regarded as biassed on that account. Numbers R and S were cut from the same piece of material and might be assumed to be of equal quality. Under suggestion, R took first place S and the last place.

Weight and Thickness

Weight and thickness are again closely associated at +·75. The Experimenter's Touch is determined by thickness and not much by weight; the Touch (Adults) being influenced by both and the Touch (Boys) only by weight. Thickness has a stronger influence in this range than in the others, due probably to the "lofty" handle described by some as "flannelly".

Group Agreements

The Touch (Adults and Boys) are agreed at +·62, weight being a common factor but not thickness. The experimenter disagrees with both, probably because the flannelly feel has more influence with him as indicated by the thickness +·75. The finish of this range was a medium between the milled and clear finishes and in the general average of +·33 also shows a mid-position between +·16 and +·53 respectively.

THE BASIS OF JUDGMENT BY TOUCH

Yarn Construction

In the previous inquiry it was shown that the final mass gradings of the fifty judges, on a full judgment correlated to the milled and clear finishes gave an agreement of +·99. This indicates that the method of yarn construction was the fundamental point of agreement between the two ranges. The question now arises whether the Adult judges, the Boys, and the Experimenter, by Touch alone, give a similar agreement. These results are—

22 Adults	+ ·64
6 Boys	+ ·53
Experimenter	+ 1·00

This shows that the method of yarn construction is again the deciding factor. It is noteworthy that the Experimenter should have placed the two ranges after averaging 100 trials of each by Touch in absolutely the same order. Yet there is a striking difference between all the groups in their order of preference for yarn types—broadly represented by British, Continental, or Mixed.

Choice	1st	2nd	3rd	4th	5th	6th
50 Judges	Br.	Br.	Con.	Mix.	Mix.	Mix.
22 Judges	Con.	Br.	Br.	Mix.	Mix.	Mix.
6 Boys	Br.	Con.	Br.	Mix.	Mix.	Mix.
Experimenter	Br.	Br.	Mix.	Mix.	Mix.	Con.

Weight and Thickness

The weight of the samples might influence the groups, especially as there is an agreement of +·82 between the two ranges by weight. Both having been cut in separate lots in purely a chance order, it would appear that the weight of the cloths per unit area by reason of their yarn construction, is decisive and not the actual size and weight of the samples themselves. The Experimenter's Touch grading of the two ranges is in absolute agreement at 1·00, showing an emphatic bias by Touch. The fifty judges on a full judgment averaged +·99; the twenty-two Adults on Touch +·64; and the Boys on Touch +·53, showing only a tendency to be influenced by weight. Is weight, thickness, or "handle" the cause of these agreements? The averages of the two range agreements are given in Table IV.

Table IV

	Weight	Thickness	Adults Trained Touch	Boys Untrained Touch	Experimenter Biassed Touch
Full Judgment ...	·25	—·13	·83	·59	·63
Touch (Adults) ...	—·12	—·39	—	·73	·20
(Boys) ...	—·20	—·23	·73	—	·22
Experimenter ...	·91	·73	·20	·22	—

Bias of Judgment

It has already been noticed that thickness and weight have opposing effects on judgment in the milled and clear ranges, yet there is an agreement on yarn construction of +·99. That these factors do not play an important part is shown by the small disagreements on weight and thickness; though the biassed Touch of the Experimenter in this direction is well defined on both finishes. This biassed Touch is only in slight agreement with Touch (Adults) at +·20 and Touch (Boys) at +·22, showing that weight and thickness are not the bases of judgments. As, however, the agreements are very high, first between the full judgment and the Touch (Adults) at ·83 both groups being composed of experts and secondly between the Touch (Adults) and the Touch (Boys) (untrained technically but well trained educationally) at +·73 *it seems that the basis of highly-skilled judgment is some delicate natural Touch for which there is yet no absolute physical measure.* Further experiments point clearly to the possibility of measuring the sense of touch. A paper, "A Measure of Tactile Sense" is now in course of preparation.

THE FLUCTUATION IN PERSONAL JUDGMENT

Throughout the grading, mass judgment is seen to have stable results. The dominant ideas in a judge's mind by repeated trials or in the minds of a number of judges with one trial each, gives a fairly sound judgment. The mass judgment of a number of trained or experienced persons might well be termed the "trade opinion" of the cloths, whilst numerous experiments by one person might equally be termed a "personal judgment". The degree of reliability of both is recorded by averaging the agreements and comparing them with the probable effect of chance.

"Standard" and "Personal" Touch

This "trade opnion" of the Adult judges may for convenience be here called the "Standard Touch"; the repeated judgments in individuals as "Personal Touch". Assuming that the gradings arrived at on the three ranges are a fair trade judgment (on the sense of Touch alone), the averages of five opinions of one individual may be usefully compared with it. The same average also indicates the stability of the personal judgment of each person. It may be well first to examine the reliability of the individual's opinion before dealing with his comparison with others.

"Personal" Touch

The "Personal Touch" arrived at by averaging five trials of three ranges, of the twenty-two judges, ranges from +·88 to +·41, the average being +·63.

Table V shows the variation in the gradings by Touch alone of the three ranges by the first five and the last five judges.

Table V

First Judges	R4	R5	R6	Average	Last Judges	R4	R5	R6	Average
H	1·00	·87	·78	·88	A ...	·46	·26	·52	·41
C	·85	·99	·76	·87	Q ...	·25	·64	·33	·41
D	·92	·75	·80	·82	J ...	·54	·27	·46	·42
G	·79	·76	·82	·79	Y ...	·39	·71	·21	·44
B	·81	·92	·57	·77	T ...	·51	·64	·22	·46
Average for 5 judges ...	·87	·86	·77	·83		·43	·50	·35	·43
Average for 22 Judges	·62	·68	·60	·63		·62	·68	·60	·63

The stability of individual judgment is noteworthy in the high figure of agreement between judges H and C which is in contrast with that for A and Q. When new conditions are presented by a new finish, such as that of R5 and R6 following R4, the figures of the sound judges still remain stable. Whereas in Q and Y there are much wider variations under the new conditions. It will be noted also, that on average, the twenty-two judges graded the three ranges with about equal solidity—another indication of the value of mass judgment.

The six boys, totally unacquainted with textiles, give the results set out in Table VI.

Table VI

No.	Age		Headmaster's Report	R4	R5	R6	Average
	Y.	M.					
BH_5	15	10	"Very good, almost excellent"	·86	·70	·84	·80
BI_2	15	2	"Intellectually inclined"	·61	·65	·54	·60
BH_4	14	11	"Distinctly poor"	·41	·85	·44	·57
BI_3	15	8	"Intellectually inclined"	·47	·41	·67	·52
BI_1	18	0	"Matriculated: concentrated mental effort three years	·46	·56	·48	·50
BH_6	15	5	"Moderate"	·09	·26	·37	·24
			Average	·48	·57	·55	·54
			Average for 22 Adults	·62	·68	·60	·63

In BH_5 is represented the all-round excellent boy, who would probably make good, if sufficiently interested, in any industry or profession into which he might enter. It is suggested that a boy who can repeat, by Touch alone, such difficult tests, is worthy of the best technical training available, so as to use his natural ability. The last boy, BH_6, was "moderate" at school, and good in manual work, but his appreciation of small differences of this kind was low. BH_4, though "distinctly poor" at schoolwork, was selected because of his handwork; his sense of Touch proving high, he might well be placed where more delicate manual work was required.

The three boys, BI_1, BI_2, and BI_3, were obviously considered better than the handwork boys, BH_4, BH_5, and BH_6, at school, but on average they proved about equal in these tests. These six selected individuals do not probably represent boys in general of the same ages.

An analysis of the fluctuation of judgment by the experimenter will be dealt with later (see p. T167) but for comparative purposes the best set and the worst set of five judgments with the average of 100 trials are presented.

	R4	R5	R6	Average
Best set of five	·91	·91	·68	·83
Worst set of five ...	·46	·23	·05	·25
Average of 100 trials	·67	·57	·48	·57

Weight and thickness have been shown to bias the judgment of the experimenter. By averaging these two factors and comparing this average with the 100 trials above, the bias is again given—R4 milled = +·91; R5 clear = +·82; R6 milled = +·52.

THE DEVIATION OF PERSONAL JUDGMENT FROM MASS JUDGMENT

"Standard Touch" should fairly represent a "trade opinion" on Touch. Comparison (see Table VII) with the gradings of individual judges indicates how far these judges are individually able to assess this "trade opinion".

Table VII

First 5 Judges	R4	R5	R6	Average	Last 5 Judges	R4	R5	R6	Average
C ...	·64	·87	·52	·68	V ...	·03	−·14	·04	−·05
R ...	·79	·60	·58	·66	M ...	·11	·15	−·38	−·04
B ...	·69	·74	·42	·62	A ...	·16	·20	−·45	·03
D ...	·28	·77	·77	·61	L ...	·03	·35	−·22	·05
E ...	·48	·65	·15	·43	T ...	·20	·28	−·15	·11
Average ...	·58	·73	·50	·60		·11	·17	−·23	·02
Average for 22 Judges	·32	·39	·12	·28		·32	·39	·12	·28

The ability to make a decisive judgment which at the same time agrees closely with "trade opinion" has definite commercial value. Judge C for example recorded an opinion on three ranges of +·87 (see Table V) which agreed with the "trade opinion" as closely as +·68—both above the average. D and B have also sound and similar judgments. It is significant that the best judges are good all-round technical and practical men.

The last five were characterised by—declining ability due to age; only a few years' training at middle age; lack of fixed responsibility; preference for lower grade goods denoting less desire for fine differences.

Taking the "Standard Touch" as a basis comparison the boys, ranked in the order of personal stability, show the following results, Table VIII.

Table VIII

Boy	Personal Rank	Trade Rank	R4	R5	R6	Average
BH_5	1	1	·26	·50	·59	·45
BI_2	2	3	·21	·63	·10	·31
BH_4	3	4	·00	·37	·53	·30
BI_3	4	5	·34	·30	·09	·24
BI_1	5	2	·40	·45	·33	·39
BH_6	6	6	·05	−·05	·24	·08
		Average of Boys	·21	·37	·28	·20
		Average of 22 Adults ...	·32	·39	·12	·28

The variations on each range are greater for the boys than for the adults: the best boy is only equal to 66% of the best adult. At the other end of the ranking there is not much to choose: on average there is no difference. At first sight it is not easy to understand why the boys judge so well. An explanation has already been offered (see p. T161) that the basis is some delicate natural touch, as yet unmeasured physically. Further confirmation is seen in the "personal" and "trade" grading of the boys which closely agree, although the trade grading was entirely determined by others. An agreement of +·73 indicates that their "personal" judgment also represents a fair "trade" judgment.

As there can be no connection between the two, some common factor is present. This is neither weight nor thickness but has been shown to be some minute difference in yarn construction detectable by Touch alone by persons of good intelligence irrespective of training and experience.

DETECTION OF NATURAL TOUCH ABILITY

It would appear that this subtle variation in judgment between one person and another is one of degree rather than of kind. In this case is should be possible to rank the individuals not perhaps from a commercial, but purely from an educational point of view.

A Trade Standard is necessarily confused by the enormous variety of considerations entering into the judgment of a skilled judge. Not only has he to form his own conclusions but he must attach even more importance to what he thinks to be the opinion of his customers. If the twenty-two judges be ranked in order of Touch ability, accepting the "Standard Touch" as a basis and comparing this with the average of five "personal" judgments there is an agreement of +·40. It would not be therefore allowable to accept the selection of one as being representative of the other, though the two are moderately agreed. In the case of the Boys and from the same standards there is an agreement of +·73 which does in fact represent a well-founded agreement.

The simpler way of arriving at a comparison between the trained and untrained person is to eliminate as many of the factors as possible which lie outside the main facts of judgment, e.g. fashion may demand a clear in preference to a milled finish. The trained individual would probably judge the clear finish with the greater reliability because of recent practice; the boys might be attracted by the fullness of the milled finish. In such case the results are not necessarily of equal value.

A personal judgment can be well demonstrated by repeating the grading of each range five times and accepting the average as the standard. Whatever dominant idea is present in the mind of the trained or untrained judge will record itself in the final issue and those minor points which fluctuate will, by confusion, have little influence. If the two groups be ranked in order of stability of personal judgment the agreement, by Touch only, is—

	R4	R5	R6	Average
22 Trained Men ...	·87	·73	·73	·78
6 Untrained Boys	·89	·73	·73	·78

This shows a very close relationship in principle and indicates a basis of measuring the degree of Touch ability present in each person.

In contrast to this the rank in order of stability of personal judgment compared with the ranking of the trade opinion shows—

	R4	R5	R6	Average
22 Trained Men ...	·31	·43	·23	·32
6 Untrained Boys	·82	·73	·64	·73

The "personal" opinion appears to be in conflict with the "trade" opinion in the trained men, suggesting confusion of thought. In the minds of the untrained boys the relatively few basic facts register themselves and these with certainty. Also it should be noted that a subtle sense of Touch was the most prominent feature in judgment. It would not be permissible therefore to accept the basis of a "trade opinion" as a measure of the reliability of "untrained" touch.

A simple method is described in a previous paper* and deals only with the placing of the best and worst cloths in a range, because it is shown definitely that these adequately represent the grading of the whole range. Ranking the same persons in the same way and comparing this "Measure of Reliability" of Personal Judgment with the full grading, the results are—

	R4	R5	R6	Average
22 Trained Men ...	·75	·73	·72	·73
6 Untrained Boys	·95	·73	·73	·80

or the "Measure of Reliability" of Personal Judgment compared with Trade Judgment, gives—

	R4	R5	R6	Average
22 Trained Men ...	·31	·41	·37	·36
6 Untrained Boys	·73	·73	·41	·62

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* *J. Text. Inst.*, 1926, (**17**), T619, lines 28–46.

It is suggested, therefore, that the best way to measure untrained ability is to allow it to be self-contained. By inviting an individual to grade a range of cloths five times and then calculating the decision on what may be termed the stability, or strength of decision of the whole, it will give a reliable indication of the probable value of a technical training for that individual.

THE EFFECTS OF SHORT PRACTICE

Repetition of the tests has been shown to give a more balanced judgment of the cloths than a single grading. From the "Standard Touch" some indication of the effect of practice might be drawn. Taking the average agreements between the Touch (Adults) judges on each of their five trials, the results are—

	R4	R5	R6	Average
First Trial	·58	·59	·59	·58
Second Trial ...	·65	·74	·57	·65
Third Trial ...	·69	·71	·51	·64
Fourth Trial ...	·58	·70	·69	·66
Fifth Trial	·61	·65	·64	·63
Average ...	·62	·68	·60	·63

These gradings were carried out independently, yet there is a remarkable stability on the different trials which practice seems to have changed very little. The boys on the same basis show—

	R4	R5	R6	Average
First Trial	·70	·69	·39	·58
Second Trial ...	·40	·59	·52	·50
Third Trial... ...	·45	·68	·35	·50
Fourth Trial ...	·31	·37	·67	·45
Fifth Trial	·54	·59	·81	·65
Average ...	·48	·57	·55	·54

The boys show an average variation between extremes on the three ranges of +·39 and the men only +·15 though practice would seem to have caused some improvement in the fifth trial by the boys.

THE EFFECTS OF A LONG PERIOD OF PRACTICE ON THE JUDGMENTS OF THE AUTHOR

In order to trace the effects of a relatively long period of practice the experimenter graded the three ranges 100 times each. No time was recorded but an hour and a half each day for thirty days would certainly have been required to complete the three ranges. As it was not possible to work every day, six weeks to two months were occupied in these experiments.

Some indication has already been given (see p. T158) that weight and thickness did much to influence the average decision. As each of the three ranges of samples were cut from the piece and gimped independently in purely chance order, any variation in the area and the weights (see Tables I, II, and III) of the samples were too minute to indicate any changes in yarn spinning methods. Yet it is significant that in ranges R5 and R4, cloths made from identical yarns, yielded identical results, though the finish was quite different and the strength of the decisions was more marked in the milled than in the clear finishes. As the two ranges produce the same results and R6 is in agreement, +·75, this standard grading of cloths may be termed "Touch, 300" and comprised 5,100 placings or units of judgment.

The questions which it seemed desirable to answer are given below and from the data an attempt has been made to reply to them.

What effect has long practice on—

(1) *The strength of the decisions, disregarding any daily change of opinion.*

(2) *The strength of decision of five trials on R4 milled followed by five trials of R5 each day.*

(3) *The daily averages on each range in their relation to the standard "Touch, 300" of the Experimenter.*

(4) *Improvement or otherwise during the five trials of each range each day, in strength of decision, and in accuracy.*

(5) *The first set of gradings in regard to accuracy in comparison with the four succeeding ones.*

(6) *Judging the samples in cuttle form or fully opened, and how these affect the accuracy of the decisions.*

1—The extreme strength or weakness of the decisions vary in the hundred trials of each range as follows—

	Highest	Lowest	Average of 100
R4 Milled	1·00	— ·26	·68
R5 Clear	1·00	−1·00	·57
R6 Milled	·95	−1·00	·48

This clearly shows the divergent opinions it is possible for one person to have at different times. A contrast of stable and erratic judgments is given for each trial-

	R4		R5		R6	
	Stable	Erratic	Stable	Erratic	Stable	Erratic
First Trial	·73	·95	·95	·53	·94	— ·48
Second Trial ...	·95	·41	·95	·00	1·00	−1·00
Third Trial ...	·95	·82	·95	·89	·46	1·00
Fourth Trial ...	·95	— ·26	·89	— ·26	·46	·00
Fifth Trial	·95	·41	·82	·00	·46	·75
Average ...	·91	·47	·91	·23	·66	·05

This implies that during the period of judgment either a decisive and stable opinion exists or that, for some reason, the mind is wavering.

A complete change from dry weather to a very wet day suggested that a change in judgment might be expected, but the average of ten trials gave an agreement of +·06 above the normal.

2—Comparing the first ten series of gradings in each cloth, there is an agreement of +·13 and in the second ten a disagreement of —·26 giving an average of —·06. This seems to imply that a stable set of judgments on one finish does not necessarily mean stability in grading another finish.

3—From almost a unique standard of touch in which neither of two finishes has been shown to have influenced the judgments of yarn construction, some observations on fluctuations are available. A comparison may be made between the strength of decision and the accuracy as measured from the Standard "Touch, 300".

	R4	R5	R6	Average
Strength of decision ...	·68	·57	·48	·57
Accuracy	·52	·42	·24	·39
Difference ...	·16	·15	·24	·18

To this extent, therefore, there is a variation in the selection of samples each day. It must, of course, be borne in mind that these samples represent the maximum difficulty and on a most restricted judgment by Touch alone.

Some contrasts in accuracy are recorded.

	R4		R5		R6	
	Stable	Erratic	Stable	Erratic	Stable	Erratic
First Trial	·73	—·26	·99	—·65	·46	·46
Second Trial ...	·99	·00	·73	·00	·75	—·48
Third March ...	·73	·53	·53	—·26	·75	·46
Fourth Trial ...	·89	—·26	1·00	·53	·75	— ·15
Fifth Trial	·73	—·65	·89	·00	·75	—1·00
Average ...	·84	—·13	·83	—·08	·69	—·14

In the case of R4, +·84 was recorded one day and —·13 the next. The former had a "decision" of +·91, and the latter of +·55. This shows that a sound judgment may be strong one day and on the next, that a moderate "decision" may be associated with a poor judgment.

4—To measure improvement by practice the scores should show a steady advance from the beginning to the end of the tests. The agreements are here stated for the ranking of ten series of five judgments each.

	R4		R5		R6		
	First Fifty	Second Fifty	First Fifty	Second Fifty	First Fifty	Second Fifty	Average
Strength of decision ...	—·38	·07	—·26	—·69	—·26	—·20	—·28
Accuracy...	·07	·07	·18	—·04	—·63	·07	—·05
Average	—·15	·07	—·04	—·36	—·44	—·06	—

Practice has not improved either of the main factors of judgment. This does not definitely imply no improvement by practice, but it does show that repetition is likely to cause irritation or fatigue thus reducing the powers of judgment.

5—This question may be re-stated as follows. Is the first arrangement of a range likely to be as accurate as any of the following arrangements ? Separating the "strength" of the decisions from the "accuracy" the records show—

	"Decision"				"Accuracy"			
	R4	R5	R6	Average	R4	R5	R6	Average
First Trial	·73	·59	·52	·61	·54	·52	·45	·50
Second Trial ...	·70	·42	·23	·45	·62	·22	—·08	·25
Third Trial ...	·72	·57	·55	·61	·54	·40	·34	·43
Fourth Trial ...	·62	·60	·56	·59	·39	·56	·35	·43
Fifth Trial	·64	·65	·57	·62	·53	·41	·15	·36
Average ...	·68	·57	·48	·57	·52	·42	·24	·39

There is practically no variation of four trials in "decision". On "accuracy" the first arrangement is definitely the best. The second arrangement has both less "decision" and is less "accurate" than any of the others. This confirms observation in other investigations by the experimenter, that second judgments are often bad, sometimes to the extent of reversing the previous and succeeding arrangements.

Regular practice for one to two hours a day on the same samples for two months does not materially alter the judgment, by Touch, of a trained man. His first judgment of a range is probably as sound as any he is likely to make afterwards provided health and environment are the same. With the untrained person there is no evidence in this inquiry on long practice.

6—It was noticed that different judges in the previous inquiry handled the samples in different ways, from being fully opened to remaining in cuttle as they left the bag. These two extremes were tested by the Experimenter himself, the results being—

(*a*) First, the differences between the samples judged in cuttle or open on the "strength of decision" of 150 arrangements.

	R4	R5	R6	Average
Cuttle	·67	·58	·53	·59
Open	·68	·56	·42	·55
Average	·67	·57	·48	·57

The decision and stability of judgment is not, therefore, affected by the difference in method.

(*b*) Second, the reliability of judgment obtained from the two methods compared with the final Touch grading of cloth by the experimenter himself.

	R4	R5	R6	Average
Cuttle	·43	·39	·26	·36
Open	·60	·46	·23	·43
Average	·51	·42	·24	·39

On two ranges there is a definite advantage in accuracy in opening the samples fully out, but from these figures it would appear that a decisive set of judgments can be given by either method.

In the worsted industry the fundamental basis of judgment may be exactly the same in two groups of persons or in two individuals and yet their opinions may vary from a "moderately agreed" to "agreed in the main" basis. This seems to cause confusion to representatives of other industries whose raw materials are not so variable or which can be measured with accuracy by mechanical appliances. An "opinion" is of importance to worsted manufacturers and this in turn is subject to considerable fluctuation by mental and physical changes within the individual and by environmental changes over which he has little or no control.

7—The Time Factor being of importance it is desirable to find a simple, yet reliable, method for assessing "strength" of decision and "accuracy" of judgment by one figure.

That the "Measure of Reliability" does this effectively is shown by the following, which compares this measure with the average of those already given on "strength" of decision, and with the "accuracy" of the arrangement of each range of cloths on a basis of the Standard (in this case) 100 judgments.

	R4		R5		R6		
Fifty	First	Second	First	Second	First	Second	Average
Strength of decision ...	·62	·92	·81	·94	·72	·75	·79
Accuracy...	·86	·86	·62	·75	·75	·81	·77
	·74	·89	·71	·84	·74	·78	·78

This is a remarkably high agreement, is fairly stable throughout, and should be considered sufficient for all requirements.

MEASUREMENTS OF THE "TOUCH JUDGMENT" ABILITY OF AN INDIVIDUAL JUDGE—MD$_1$

The series of experiments now to be described were carried out by one of the fifty judges whose services had been secured for the work described in a previous paper*. He was also one of the twenty-two "touch-judges" whose records are given above. He was a manufacturer of botany dress goods and

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J.T.I.*, 1934, **25, T89–T105.

regarded in the trade as a competent judge. He volunteered to perform a further series of cloth gradings and the Experimenter's thanks are here warmly accorded to him for his loyal adherence to a task which proved irksome long before it was completed.

Indications of the Personal Ability of MD_2

The highest score recorded by any one of the fifty judges in their "full" judgments was +·77. MD_2 scored +·74. On the various ranges previously judged his figures compared as below with the average of fifty judges—

	MD_2	Average of 50 Judges
R1—sight only	·81	·46
R1—touch only	·37	·15
R2—milled	·67	·53
R3—clear	·76	·49
R4—milled	·53	·37
R5—clear	·99	·51
R6—suggestion	·75	·14
Average	·70	·38

In the Sight and Touch tests he was remarkably good and resisted the "suggestion" in range R6 at +·75—under a less rigid scheme he might be stated to have resisted absolutely in that he placed the two duplicates next each other in first and second places.

Another proof of his ability was shown in range R3 (fifteen cloths clear finished) in which three samples were duplicated, one being marked "M" and the other "C", to suggest mule and cap. His grading placed each pair of duplicates next to each other, and in each group M had the higher place.

His agreement on the yarn differences in ranges R4 and R5 on full judgment, is +·75; the best and worst cloths being identical in both finishes. The time occupied per unit of judgment was 62 seconds, the average being 38 seconds, ranking him forty-third, thus showing a slow rate.

"Estimated Length" and "Memory" Tests by MD_2

He was next asked to estimate the length of various lines (intended to represent wool fibres) from 2⅜ inches to 4 inches each. Some lengths were duplicated and a personal suggestion was introduced twice in order to confuse him. The variations were usually ⅛ inch and not more than ¼ inch. "Suggestion" influenced him to the extent of ¼ inch in one case and not at all in the other. Including this, there was only a total displacement of ½ inch on ten estimations, an average error of 1/20th of an inch.

A test utilising twenty duplicated photographs of fibres, tops, yarns, and weaves, there being infinitesimal variations in the second group, was next devised and carried out by MD_2. One set was spread out upon a table and the subject was invited to remember the different details in each photograph; no time limit being given. The twenty photographs were then shuffled with the duplicate twenty and all were replaced on the table. MD_2 was asked to select again the original twenty, and he made a 95% correct selection.

"Touch" Data Relating to MD_2

As previously stated he was selected from the first investigation to continue the second investigation by "Touch" alone (twenty-two judges). His results were as follows—

The average of his five trials by "Touch" gave a stability or strength of decision of—

	MD$_2$	Average of 22 Persons
Range R4	1·00	·62
R5	·87	·68
R6	·78	·60
(Position—First out of 22)	·88	·63

His agreement by "Touch" with the selection of the other judges—

	MD$_2$	Average
Range R4	1·00	·32
R5	·26	·39
R6	·52	·12
(Position—Twelfth out of 22)	·56	·28

His agreement on a "Full Judgment" with the "Full Judgment" of fifty judges.

	MD$_2$	Average
Range R4	·53	·37
R5	·99	·51
R6	·75	·14
(Position—Third out of 50)	·76	·34

The stability required to give a "Full Judgment" to be compared with a restricted one on "Touch" two years later, is considerable. For MD$_2$ these judgments are in agreement to the following degree—

R4	·73
R5	·73

It is significant that (in three of the four judgments) MD$_2$ made Noble combing, cone drawing, and cap spinning, the first choice; which the fifty judges and the two hundred judgments by the Experimenter confirm. In the "clear finish" range by "Touch" he places Noble combing, cone drawing, and ring spinning as best. In all cases, therefore, the Bradford machine combinations are considered the most excellent after precautions had been taken to make the experiments impartial.

SELECTED CLOTHS FROM RANGES R2 MILLED AND R3 CLEAR MIXED TWO-FOLD AND SINGLE WARP YARNS GRADED BY MD$_2$

For this experiment five samples, each of two-fold and of single warp cloths, were taken from the full ranges of seventeen cloths in R2 milled and fifteen cloths in R3 clear finishes. The two ranges are not directly comparable as only seven out of the ten pairs of yarn combinations were identical. The grading of these seven cloths in the two finishes by MD$_2$ shows an agreement of+·26, whilst the same cloths were graded by the "Full Judgment" of fifty experts at ·50. This shows that the fundamental differences in the cloth are not generally "finish" but "yarn construction", though in isolated cases (notably in cloth O) the finish makes a complete change. MD$_2$ grading by Touch, seems to indicate the same but to a less degree.

On gradings of the ten selected cloths, MD$_2$ agrees with "previous decisions" or those of other judges as follows—

MD$_2$	R2 Milled	R3 Clear
Full Judgment compared with Full Judgment of 50 experts	·54	·81
Full Judgment compared with 10 selected cloths by MD$_2$, 50 trials by Touch alone two years later	·69	·94
Fifty Touch trials compared with opinion by Full Judgment of 50 experts	·50	·90
	58	·88

Here is shown the efficiency of MD_2; his appreciation of the clear finish indicates very sound judgment, but his dislike of the milled finish probably influenced his gradings.

First Choice Preference of MD_2

In the first inquiry on Full Judgment, it was shown that two-fold warps were preferred to singles on both milled and clear finishes, in the proportion of two to one. MD_2's opportunity for preferring two-fold warps was greater than on that occasion, yet he only recorded a slight difference with five two-fold and five single cloths—

	By "Touch" MD_2		
	R2 Milled	R3 Clear	Average
Two-fold warps	·51	·56	·53
Single warps	·49	·44	·47

By Touch alone therefore MD_2 has no decided preference.

Observations made by the Subject MD_2 during the Performance of the Special Tests

The gradings were done late in November and at times varying from 2 p.m. to 7 p.m. and on one occasion on a foggy day. Gaslight, as well as daylight, was employed, but there are no indications in the results that time and weather or atmosphere played much part in the gradings.

The physical condition of the subject was also noted and on occasion he recorded a "cold in the head", "influenza", "rough chapped hands", and having to commence the tests "after an arduous day". These indicated to him the probability of his judgment being influenced by physical condition.

When mental condition intruded itself on the subject, MD_2. recorded his impression of lack of training in this work, the handicap of being deprived of "sight", and anxiety to complete the tests. This last condition had a significant effect which will be seen from the figures recorded below.

In regard to the properties, etc. of the fabrics, he noted their surface softness as distinct from, yet involved with, their handle, pliability, and weight. He endeavoured to grade on the surface feel alone and expected thereby erratic results. Later he expressed the view that these properties were combined in "Touch sense" gradings. The "clear finished" cloths were first graded, then the "milled finished", and then each alternately, by which time the subject had expressed uncertainty as to the practical application of the tests and his own anxiety to complete them.

What does this "anxiety to get the job done" show in point of fact? In "strength of decision" the average in "milled" and "clear finish" was—

	R2M	R3C	Average
First "careful" set	·73	·69	·71
Second "anxiety" set	·58	·50	·54

and, in average group accuracy, compared with the final average of fifty trials as standard, was—

	R2M	R3C	Average
First "careful" set	·65	·53	·59
Second "anxiety" set	·34	·33	·34

Strength of decision in each of the five groups being reduced in harmony with mental conditions and entirely in disregard to the accuracy of cloth grading, accuracy was reduced to an even greater extent by the same conditions.

The subject anticipated that practice would improve his judgment; the facts are that the—

	R2 Milled	R3 Clear	Average
Improvement by practice on decision is	−·63	−·63	−·63
Do. on accuracy	−·75	−·32	−·53
	−·69	−·47	−·58

"Anxiety to be through" negatives any practice effect, the net result being that the earlier judgments from two points of view are better than the later trials. It was found in the tests made by the Experimenter on Touch, that the first judgments in each five were likely to be as sound as any of the others, with the second probably the worst. MD$_2$ did some of the trials one after the other and the results are recorded. The same tendency is present.

Trials in each Five Groups	R2 Milled Average of 10 Decision	R2 Milled Average of 10 Accuracy	R3 Clear Average of 10 Decision	R3 Clear Average of 10 Accuracy	Average
First Trials	·73	·56	·67	·56	·63
Second Trials ...	·67	·53	·52	·30	·50
Third Trials	·66	·55	·70	·44	·59
Fourth Trials ...	·60	·43	·63	·53	·55
Fifth Trials	·61	·38	·46	·31	·44
	·65	·49	·60	·43	·54

The "cold in the head, chapped hands, lack of sensitivity, and conditions of worry" seem probable causes of both the temporary fluctuations and the more permanent trend of loss of judgment.

The "Measure of Reliability" compared with Spearman's Footrule Formula shows the agreement given below and is, therefore, over an extended set of trials by restricted judgment under difficult mental and physical conditions, seen to determine quite well the question of "decision".

	R2 Milled	R3 Clear	Average
Decision	·90	·92	·91
Accuracy	·72	·58	·65
	·81	·75	·78

The time per unit was R2 milled, 34 seconds; R3 clear, 44 seconds; compared with Full Judgment time of 62 seconds. This variation may mean less care in handling.

Conclusions in Regard to MD$_2$ Gradings

The measured judgments of MD$_2$ show remarkable ability. Some of the results recorded are declared to be astonishing by those who have seen the cloths. He honoured his promise to execute an irritating task and gave the benefit of his feelings, mentally and physically not always of the best, but the results follow definite lines which might be anticipated. First judgments are at least equal to others, and more often are the best, in an experienced man. Tranquility of mind and body would appear to be desirable factors in sound judgment.

A RIGHT-HANDED TOUCH

A manufacturer (M$_1$) of 23 years' experience and one of the fifty judges, came second in rank with a score of +·75. On range R3, where three duplicates of cloths were inserted, he placed the samples second and third; sixth and seventh; and twelfth and fourteenth; making only a one place error in the last set. Several months later these six samples were again submitted to him in pairs, and he made the same selection as on the former occasion. He then found a stronger sense of Touch in his right than his left hand—the better of each pair of duplicates was declared to have a nicer Touch, though the other was "brighter and more sightly".

While acting as one of the (twenty-two) judges he declared —"If two samples are held one in each hand, and they appear to me equal, then I know that the one in the left hand is lower than that in the right. My right hand is a better judge than my left". He again obtained a stability score of +·77; of accuracy +·62; and was third judge by rank. He has since declared that the knowledge of the difference between the sensibility of his hands has been of considerable benefit to him financially and he is most particular to make use of it in his buying.

THE JUDGMENTS OF A BUYER AND AN ASSISTANT BUYER

The value of responsibility (especially financial) in developing ability is recognised in the trade, provided the other elements which educate judgment, such as continual practice, are also operative. A brief comparison between a buyer for a well-known wholesale house and his assistant may indicate the lines on which such development takes place.

	Range	B4 Buyer	AB2 Assistant	Average	Average of 50 and 22 Judges
Full Judgment	R2 Milled	·75	·67	·71	·53
,, ...	R3 Clear	·49	·33	·41	·49
,, ...	R4 Milled	·88	·99	·94	·37
,, ...	R5 Clear	·73	·53	·63	·51
Partial	I S Sight	·66	·18	·42	·46
,, ...	I T Touch	·18	—·04	·07	·15
Personal Suggestion—					
Resistance	R6	·46	·46	·46	·39
Touch only—					
Decision	R4 Milled	·52	·39	·46	·62
,, ...	R5 Clear	·56	·71	·64	·68
,, ...	R6 mid.	·61	·21	·41	·60
Accuracy...	R4 Milled	—·08	·03	—·02	·32
,, ...	R5 Clear	·25	—·14	·06	·39
,, ...	RR6 Mid.	·05	·04	·05	·12
	Average	·47	·33	·40	·43

The interesting fact is disclosed that though in these thirteen series of tests, B4 and AB2 generally may be said to rise and fall in their judgments together, the buyer is however on a higher level of efficiency at +·47 than his assistant at +·33. The huge turnover with which these gentlemen have to deal obviously demands careful and impartial judgments under favourable conditions.

PRACTICAL APPLICATIONS

The practical applications suggested by the above (and the previous) experiments may be worthy of indication as the work suggests that a sense of Touch correlates highly with a Full Judgment and may indeed be the final arbiter. To the wool trade as a whole the development of the sense of Touch is important. Fundamental differences in cloth construction can be detected by the means described and are not available by any mechanical or optical method of measurement. These experiments also indicate the possibility of detecting and of registering the degree of natural "Touch ability" in boys and girls and also would be readily employed for other training purposes. It should be the object of training to co-ordinate the employment of the sense organs with sound technical knowledge. The Experimenter has evidence in later tests, that a general measure of tactile sense is possible, applicable at all ages (except infants) and at any stage of experience or training. A simple test, with the proof of its usefulness will shortly be available.

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12—THE DISSOLUTION OF CHEMICALLY MODIFIED COTTON CELLULOSE IN ALKALINE SOLUTIONS

PART I—IN SOLUTIONS OF SODIUM HYDROXIDE, PARTICULARLY AT TEMPERATURES BELOW THE NORMAL

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I—INTRODUCTION AND SUMMARY

The term "Chemically Modified Cotton Cellulose" has been used in publications from these laboratories to denote cotton the physical and chemical properties of which have been modified by the action of acids or oxidising agents. In particular, the materials obtained by the action of acids are termed hydrocelluloses, and those produced by the action of oxidising agents, oxycelluloses. The most important properties that are thus affected are the tensile strength, the reducing power (copper number), the acidity (Methylene Blue absorption), the stability towards hot dilute alkali, the fluidity in cuprammonium hydroxide solution, and the solubility in cold concentrated sodium hydroxide solutions. The inter-relations of these properties of modified cottons have been described in numerous papers from this Institute. In particular, Birtwell, Clibbens and Geake[3] have investigated the solubility of modified cottons in sodium hydroxide solutions at the ordinary temperature; the object of the work described in the present paper was to extend the investigation to temperatures below the normal.

The use of low temperatures to facilitate the preparation of solutions of cellulosic materials in sodium hydroxide solution has been patented by Lilienfeld[17] and the effect of such temperatures in increasing the solubility of wood pulps and viscose rayons has been shown by the work of D'Ans and Jäger[9], Fukushima and Takamatsu[13], and Atsuki and Shimoyama[1].

The solubility relations of modified celluloses, like those of many other colloids, differ from those of crystalloids in that the concentration of the solute in the presence of the solid phase depends on the amount of the solid used with a given volume of the solvent. The usual method of expressing the solubility of crystalloids, as the concentration of a saturated solution, has therefore little significance when applied to a modified cellulose, and in the present paper, following Birtwell, Clibbens and Geake[3], the percentage of the material that dissolves under stated conditions is used as a measure of the solubility. When various weights of the same hydrocellulose were extracted with a given volume of sodium hydroxide solution, approximately the same percentage of each was dissolved, so that the solubility in the sense employed in this paper was practically constant; the concentration of material in solution, on the other hand, was proportional to the amount of the hydrocellulose used. This behaviour may be regarded as an indication of the heterogeneous character of modified cotton cellulose.

The results described in the present paper show that the solubility of hydro- and oxy-celluloses at any temperature is a maximum at a certain alkali concentration, and that as the temperature is lowered from the normal, the maximum solubility is greatly increased and occurs at a lower alkali concentration. Thus, for a certain hydrocellulose, the maximum observed solubilities at 15°, 0° and $-5°$ C. were 8·2, 57·5 and 82·6% and these maxima occurred at alkali concentrations of 3·0, 2·75 and 2·5*N* respectively. Maximum solubility of the hydro- and oxy-celluloses prepared from unmercerised cotton occurred at substantially the alkali concentrations quoted above, but it was found that modified cottons prepared from cotton previously swollen with concentrated sodium hydroxide solution had a maximum solubility at $-5°$ C. at a rather higher alkali concentration. Thus, a series of oxycelluloses obtained by the action of oxygen on cotton impregnated with 10*N* sodium hydroxide solution, and a series of hydrocelluloses prepared from mercerised cotton, had maximum solubilities at $-5°$ C. in 2·75 and 3·0*N* sodium hydroxide solutions, respectively.

When modified cottons are boiled under pressure with dilute alkali, the residual material is more soluble in sodium hydroxide solution at $-5°$ C. than the original modified cotton, in spite of the loss of weight that occurs during the boil. The increase in solubility is slight with hydrocelluloses prepared from unmercerised cotton, but it is considerable with hydrocelluloses prepared from mercerised cotton and with oxycelluloses of the hypochlorite series examined.

When a modified cotton is treated with 5*N* sodium hydroxide—a treatment that effects insignificant dissolution—and, after dilution of the alkali to lower concentrations, the solubility at low temperatures is determined, it is found that the maximum solubility is lower, and occurs at a higher alkali concentration, than with the modified cotton not previously treated with the 5*N* alkali. Thus, a certain boiled oxycellulose had a maximum solubility of 85·2% in 2·5*N* sodium hydroxide solution at $-5°$ C. but when it was treated in the way described above, the maximum solubility at $-5°$ C. was only 38·0% and occurred at a concentration of about 2·75*N*. Similarly, it was found that after pre-treatment with 5*N* alkali and dilution to 2·5*N* at low temperatures, the maximum solubility attained was much less than that found by direct treatment with a 2·5*N* solution at the same temperature. In contradistinction to these results, it was found by Birtwell, Clibbens and Geake[3] that pre-treatment with 6 to 10*N* sodium hydroxide followed by dilution of the alkali to the non-swelling concentration of 2*N*, all at 15° C, resulted in the dissolution of a greater fraction of a modified cotton than could be dissolved by treatment with any single solution. The effect of the rate of dilution of the alkali in the 10*N*-2*N* treatment on the solubility has been examined, and it is found that slowing down the dilution results in a diminution of the solubility.

The solubility of any modified cotton, measured under the optimum conditions at $-5°$ C. is greater the greater its fluidity, samples with very high fluidities being completely soluble. Hydrocelluloses made from unmercerised cotton, whether boiled after modification or not, have approximately the same fluidity-solubility relation, but hydrocelluloses prepared from mercerised cotton are much less soluble than materials of equal fluidity similarly prepared from unmercerised cotton. Oxycelluloses of the hypochlorite series are more soluble than hydrocelluloses of the same fluidity, but after an alkali boil, these oxycelluloses show a fluidity-solubility relation that is nearly the same as that found for the hydrocelluloses prepared from unmercerised cotton. The oxycelluloses made by the oxidation of soda cellulose, on the other hand, show the effects of previous swelling in having relatively low solubility for a given fluidity.

By means of successive extractions with sodium hydroxide solutions under suitably chosen conditions, a hydrocellulose has been separated into four fractions differing in fluidity. The fluidity of the original material was 6·2 (2% solution in cuprammonium) and fractions of fluidities 16·6, 10·8, 6·2 and 3·6 were obtained from it.

When the alkali concentration of solutions of modified cotton prepared with sodium hydroxide solutions of greatest solvent power is increased or decreased beyond certain limits by the addition of water or of more concentrated alkali, partial or complete precipitation of the modified cellulose takes place. Quantitative experiments show that at alkali concentrations within a certain region on both sides of the concentration giving maximum solvent power, much more modified cellulose can be retained in solution than can be dissolved directly, even at -5° C.

In the last section of this paper, attention is called to the similarity between the solubility relations of modified cottons in sodium hydroxide solutions at low temperatures and the swelling relations of unmodified cotton under similar conditions. On the basis of this similarity and of present day knowledge of the fine structure of cellulose, an attempt is made to explain the observations recorded in this paper. It is shown that many of the experimental results can be explained on the following assumptions—(1) that cellulose acts as a very weak acid, forming salts with sodium hydroxide; (2) that modified cottons consist of mixtures of chain-molecules of different lengths, the average length decreasing with increasing modification; (3) that the tensile strength, the fluidity and the solubility of modified cottons are all functions of the chain length frequency distribution; (4) that before dissolution of a chain-molecule can occur, the cohesive forces binding it to its neighbours must be overcome by the swelling forces; (5) that the shorter chain-molecules are more easily detached in this way than the longer. Possible mechanisms to account for the alteration of the properties of hydro- and oxy-celluloses by an alkaline boil are also discussed.

II—EXPERIMENTAL

(1) Materials

The modified cottons employed were prepared from an unspun Indian cotton (No. 217) scoured by boiling in the form of sliver with 2% sodium hydroxide solution for 10 hours at an excess pressure of 40 lb. per square inch, and from cotton linters (No. 310) similarly scoured and lightly bleached. Hydrocelluloses were prepared from these materials by the action at room temperature of a hydrochloric acid solution containing 200 gm. of hydrogen chloride per litre, various degrees of modification being obtained by varying the duration of the acid treatment; the series H3–8 was obtained from cotton No. 217, and the series SHL 1–7 from cotton No. 310. A series of hydrocelluloses (MH 1–4) was similarly prepared from cotton No. 217 that had been swollen in $7N$ sodium hydroxide and washed with water; this material is conveniently referred to as "mercerised". The oxycelluloses employed consisted of a series (OL 6–16) prepared from cotton No. 310 by treatment at room temperature with sodium hypochlorite solution of p_H 8·4 and either $0.05N$ (OL 13-16) or $0{\cdot}2N$ (OL 6-12) in available chlorine, and a series (CSO 1-5) obtained by the action of gaseous oxygen at 40° C. on cotton No. 217 impregnated with $10N$ sodium hydroxide solution[10]. The oxycelluloses prepared by means of hypochlorite solution and all the hydrocelluloses were also examined after an alkaline boil, the treatment consisting of boiling with 2% sodium hydoxide solution for 4 hours at an excess pressure of 30 lb. per square inch. The alkali-boiled materials are distinguished by the letter B after the serial number. The modified cottons have been characterised by fluidity (absolute units, 0·5% solution in cuprammonium hydroxide at 20° C.[5]) and in some cases by copper number (Schwalbe-Braidy), these values being given in Table IX.

(2) The Determination of the Solubility of Modified Cotton Cellulose

The temperatures chosen for the investigation of the effect of temperature on the solubility of modified cottons in sodium hydroxide solutions were 15°, 0°, and –5° C. In some preliminary experiments solubility determinations were made at –10° C. but as this temperature is below the freezing point of the more dilute alkali solutions employed, its use was abandoned. By selecting –5° C. as the lowest temperature to be used, it was possible to cover the whole range of sodium hydroxide concentrations of interest in this work without freezing of the solutions.

The high viscosity of concentrated solutions of modified cellulose renders the separation of the solution from the highly swollen undissolved residue difficult, and in order to keep the concentration of modified cellulose low, the ratio of modified cotton to alkali solution adopted in the systematic investigation was 1 gm. in 100 c.c. The moisture content of the modified cotton was determined, and a quantity equivalent to 1·000 gm. of the dry material weighed out. This was extracted in a 150 c.c. stoppered bottle with 100 c.c. of the sodium hydroxide solution. In determinations at –5° C. the bottle was shaken, the stopper removed and a thermometer introduced; the bottle was then cooled in a freezing mixture of pounded ice and common salt, with constant stirring of the contents of the bottle by means of the thermometer. The cooling was interrupted when the temperature had fallen to 0° and –2·5°, the thermometer removed, the stopper inserted, and the bottle vigorously shaken. When the temperature had fallen to –5°, the bottle was again shaken and again cooled to –5°. This alternate shaking and cooling to –5° was repeated three times, and the bottle then set aside for 2 hours to allow the contents to revert to room temperature. Temperature control was easier in the solubility measurements at 0°, and here the procedure was to immerse the bottle containing the modified cotton and alkali in a well-stirred mixture of ice and water, the bottle being shaken at intervals. After 1 hour at 0° the bottle was allowed to stand in the laboratory for another hour. In the measurements at 15° C. the alkali solution was cooled to 15° C. before adding the modified cotton, and the bottle containing the mixture was immersed for 2 hours in a large vessel of water maintained at that temperature, with occasional shaking.

At the end of the stated intervals, the mixtures of solution and undissolved residue were poured into 40 c.c. stoppered tubes and centrifuged at 2,000 r.p.m. By this means a clear supernatant liquor was almost invariably obtained, although with the highly modified materials in the alkali solutions of highest solvent power, the resulting solution was slightly opalescent. An appropriate volume (usually 10 c.c.) of the supernatant liquor was then pipetted out, and the cellulosic material contained in it determined by oxidation with chromic acid. This determination was performed according to the detailed procedure given by Birtwell, Clibbens and Geake[8], except that the back-titration of the dichromate was done iodimetrically with sodium thiosulphate instead of directly with ferrous ammonium sulphate solution.

The solubility is expressed as the percentage of the material that is dissolved; in calculating it, any change in the volume of the liquid phase that may occur by reason of the dissolution of modified cellulose or of absorption of solution by the undissolved residue is neglected. If a modified cellulose is completely soluble, and if it is assumed that the dissolved material has the normal specific volume of cellulose the error introduced by the first factor is about 0·6%. Materials that appeared to be completely soluble gave solubilities of 96-98%, results that are probably due partly to this neglect of the volume change and partly to the departure of highly modified celluloses from the composition $C_6H_{10}O_5$ assumed in the analysis.

The conditions employed in the extraction of the modified cottons with alkali are entirely abitrary; but by adhering to a standard procedure results are obtained that are comparable among themselves and that for given conditions are reproducible within 1 or 2 per cent. Experiments at 15° and 0° C. showed that increasing the time of extraction to 24 hours produced only a slight increase in the solubility, and it will be shown in Section II (5) that even after extraction for 10 days at 15° C. the solubility is but little higher than that found after extraction for 2 hours. It was found that at 0° and –5° C. higher solubilities were obtained by cooling the alkali solution to the required temperature before adding the modified cotton than by following the procedure described above; thus with the oxycellulose OL7/B in 2·5 *N* sodium hydroxide solution the solubilities of 60·2% and 85·2% at 0° and –5° C. respectively obtained by the standard method were increased to 81·4% and 92·2% by cooling the alkali solution before adding the oxycellulose. In determinations at 15° C. the effect of the temperature at which the alkali solution and modified cotton are mixed is pronounced, and serious errors may be caused by adding the modified cotton to the solution at "room temperature" and then cooling to 15° C. For example, the solubility of the oxycellulose OL7/B in 3·0*N* sodium hydroxide solution at 15° C. was 10·5% when the oxycellulose was added to the solution at 15° C. but 6·8% when the alkali solution was at 20° C. when the addition was made. Owing to the difficulty of separating the solution from the undissolved residue at 0° and –5° C. the procedure adopted for the determination of the solubility at these temperatures involves the reversion of the solution to room temperature before the separation is made. Experiments showed that with alkali solutions of concentrations up to 2·75*N*, the concentration of solutions of modified cellulose prepared by extraction at –5° C. remained substantially unchanged when the solutions were kept at 15° C. for 10 days in the presence of the undissolved residue, whilst with alkali solutions of higher concentration, the modified cellulose concentration fell only very slowly. It therefore seems probable that measurement of the concentration of cellulosic material after 2 hours gives a good approximation to the concentration at the end of the extraction at the low temperature. Detailed results of the effect of allowing solutions prepared at –5° C. to stand at 15° C. are given in Section II (5). Another factor that might effect the determination of solubility, *viz.* the ratio of alkali solution to modified cotton, has been investigated, and the results are given in the next section.

No attempt was made to exclude air from the modified cellulose during the extraction, except when the latter was prolonged beyond 2 hours, for it has been shown in a previous paper[10] that the conditions of temperature, alkali concentration and duration of exposure to air employed are such as to produce but little effect on the properties of a modified cellulose.

Solutions prepared from materials of low copper number (*e.g.* alkali-boiled modified cottons) may be preserved for long periods without noticeable change, but if the modified cotton dissolved has a high copper number, the solution gradually becomes yellow on standing. This suggests that the type of decomposition that takes place during the alkali boiling of modified cottons proceeds slowly in cold concentrated alkali solutions.

(3) The Effect of Variation of the Ratio of Modified Cotton to Sodium Hydroxide Solution

It is a characteristic of solutions of homogeneous substances that at a given temperature the concentration of the solution in equilibrium with the solid phase is independent of the amount of the solute used. Of many substances that form colloidal solutions, however, this is no longer true; the concentration of the solution increases with the amount of the solid treated with a given volume of the solvent. Neuenstein[19] has shown that when sulphite pulp is extracted with solutions of sodium and potassium hydroxide at the ordinary temperature, the concentration of cellulosic material in solution depends on the ratio of pulp to alkali solution used.

The effect of varying the amount of modified cotton cellulose used per 100 c.c. of sodium hydroxide solution has been determined with the hydrocellulose H4/B. Various weights of this material were extracted, in the way already described, with 100 c.c. of 2·5N sodium hydroxide solution at 0° C.; the results obtained are recorded in Table I. They show that at ratios of modified cotton to alkali solution up to 2·5 gm. per 100 c.c. the concentration of the dissolved material is practically proportional to the amount of hydrocellulose used, *i.e.* the fraction dissolved is constant. Above this ratio, the concentration increases slightly less rapidly than corresponds to the linear relation, or the fraction dissolved decreases slightly. There is some uncertainty about the results for the fraction dissolved at the highest ratios, however, since as the ratio is increased the volume change due to dissolution of modified cellulose and to absorption of solution by the undissolved residue, which are neglected in the calculation of the fraction dissolved, become more important. Further, as the ratio increases, the concentration of sodium hydroxide in the solution is progressively diminished, owing to the well-known preferential absorption of sodium hydroxide by cellulose. Nevertheless, the results clearly show that only a certain portion of the hydrocellulose is able to dissolve, and that at the ratios of hydrocellulose to alkali solution here employed the solution is far from saturated with respect to this soluble portion.

Table I

Hydrocellulose H4/B in 2·5N Sodium Hydroxide Solution at 0° C.

Weight of hydrocellulose used per 100 c.c. (grams)	0·35	0·70	1·00	1·50	2·00	2·50	3·00	3·50
Concentration of cellulosic material in solution (gm. per 100 c.c.)	0·191	0·371	0·533	0·799	1·078	1·336	1·524	1·815
Per cent. of available hydrocellulose dissolved	54·6	53·0	53·3	53·3	53·9	53·4	50·8	51·9

(4) The Effect of Alkali Concentration and Temperature on the Solubility of Modified Cottons

The effect of alkali concentration and temperature of extraction on the solubility of modified cotton celluloses may be illustrated by reference to the results obtained with the hydrocellulose H4/B, and with the oxycelluloses OL7/B and CSO 4. The solubility data for various concentrations of sodium hydroxide at temperatures of 15°, 0° and –5° C. are recorded in Table II, and those relating to the hydrocellulose are shown graphically in Fig. 1. The main features of the curves showing the relation between the percentage of the modified cellulose dissolved and the alkali concentration are that at each temperature there is a maximum solubility at a certain concentration of sodium hydroxide, and that as the temperature is reduced this maximum solubility increases greatly and occurs at a lower alkali concentration. Thus for the hydrocellulose H4/B, the maximum solubilities observed at 15°, 0° and –5° C. are 8·2, 57·5 and 82·6%, and occur at alkali concentrations of 3·0, 2·75 and 2·5N respectively. The results obtained with the two oxycelluloses are qualitatively similar to those obtained with the hydrocellulose.

Table II

Concentration of Sodium Hydroxide Solution (normality at 18° C.)	% Dissolved								
	Hydrocellulose H4/B (Fluidity = 32·4)			Oxycellulose OL7/B (Fluidity = 34·1)			Oxycellulose CSO4 (Fluidity = 45·4)		
	15° C.	0° C.	–5° C.	15° C.	0° C.	–5° C.	15° C.	0° C.	–5° C.
1·75	0·7	1·2	3·0	1·0	1·5	3·3	—	7·3	30·8
2·00	1·1	3·0	26·0	1·4	3·8	35·6	3·5	25·1	64·6
2·25	1·9	23·6	71·3	2·5	36·6	72·4	7·4	49·5	86·0
2·50	3·6	53·3	82·6	4·4	60·2	85·2	15·4	73·7	94·5
2·75	6·3	57·5	76·3	7·8	62·7	77·4	22·4	82·4	94·6
3·00	8·2	40·1	62·1	10·5	42·3	65·2	22·3	73·2	88·1
3·25	7·2	—	—	8·6	—	—	—	—	—
3·50	5·7	12·1	21·1	6·3	13·4	20·7	12·8	45·6	69·1
4·00	3·2	4·7	8·5	3·4	6·7	10·7	7·6	17·8	27·6
5·00	1·4	1·8	2·3	1·7	2·1	3·2	4·1	6·8	9·0

(5) Prolonged Extraction of a Modified Cotton at 15° C. and the Effect of Keeping at 15° C. after Extraction at —5° C.

The solubility of an oxycellulose OL8/B at 15° C. was determined as already described after extraction for 2 hours, and the bottles containing the solutions and undissolved residues were then evacuated, filled with nitrogen and kept in a thermostat at 15° C. for 10 days. The solubilities were determined after 4 and 10 days, and the results obtained are given in Table III. They show that prolonging the time of extraction from 2 hours to 10 days increases the solubility only slightly.

Preliminary experiments on the effect of allowing solutions prepared by the extraction at –5° C. of an oxycellulose with 2N and 4N sodium hydroxide solution to stand at room temperature showed that while the modified

Table III

Time of Extraction	% Dissolved									
	Concentration of Sodium Hydroxide (normality)									
	1·75	2·00	2·25	2·50	2·75	3·00	3·25	3·50	4·00	5·00
2 hours	2·6	4·3	8·6	21·5	37·1	38·0	25·8	17·0	10·0	5·4
4 days	3·2	5·5	10·4	22·9	38·9	39·8	28·0	19·5	11·7	6·1
10 days	3·7	6·3	10·4	23·2	39·2	40·1	28·0	19·8	12·1	6·2

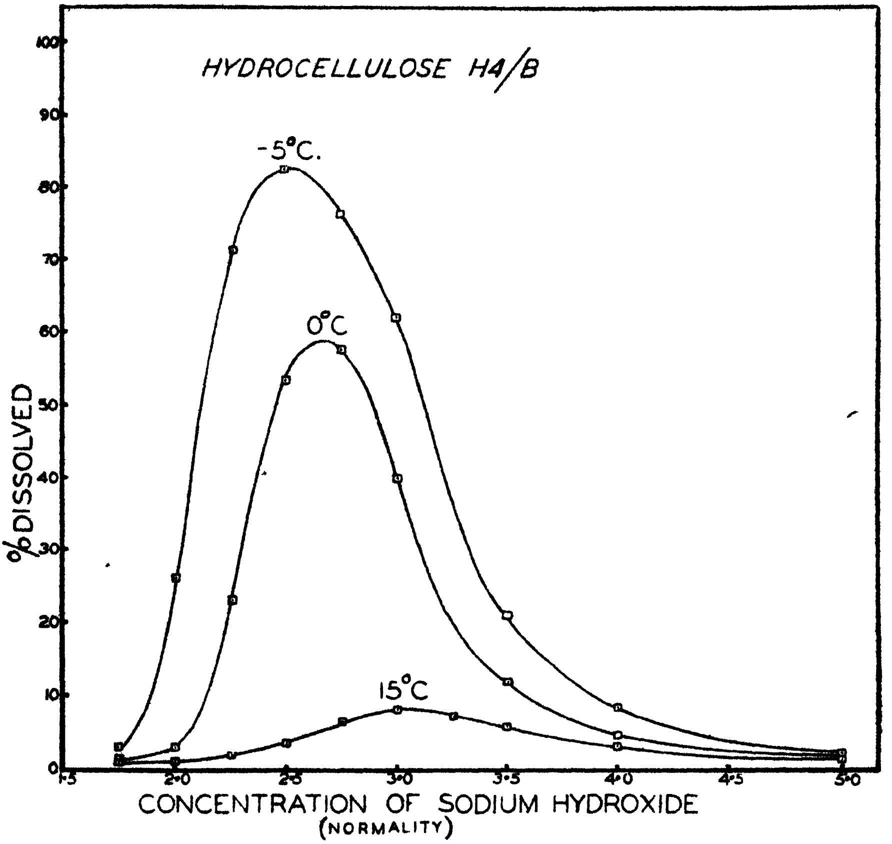

Fig. 1

cellulose concentration of the solution in $2N$ alkali solution was unchanged after 6 days, the concentration of the solution in $4N$ alkali slowly fell and finally became virtually constant after 8 days. The effect of standing at 15° C. after extraction at −5° C. was then examined with an extended series of alkali concentrations. The solubility of the oxycellulose OL8/B was determined after extraction at −5° C. in the standard way described, and then the mixtures of solution and undissolved residue were kept at 15° C. as described in the preceding paragraph. The concentrations were determined after 5 and 10 days, with the results given in Table IV. The Table shows that with alkali concentrations up to $2{\cdot}75N$, the solubility is practically unchanged after 10 days, but at higher alkali concentrations there is a fall in the solubility

Table IV

Time of Standing	% Dissolved										
	Concentration of Sodium Hydroxide (normality)										
	1·75	2·00	2·25	2·50	2·75	3·00	3·25	3·50	3·75	4·00	5·00
2 hours	18·3	59·9	96·2	96·5	95·7	80·6	69·4	58·4	45·2	31·3	10·0
5 days	18·9	59·7	96·5	96·8	96·0	77·7	62·3	47·8	26·2	12·5	4·7
10 days	19·1	59·6	96·5	96·8	96·2	76·0	59·1	43·9	16·8	6·2	3·3

that increases as the alkali concentration increases. At alkali concentrations above 3·75*N* the final solubilities are lower than those found by extraction at 15° C. for 10 days without pre-treatment at –5° C.

(6) The Relation between Alkali Concentration and Solubility at —5° C. for Modified Celluloses Prepared from Cotton Swollen before Modification

The results given in Table II show that a hydrocellulose and an oxycellulose prepared from cotton not previously swollen have a maximum solubility at –5° C. in 2·5*N* sodium hydroxide solution. The variation of solubility at –5° C. with concentration of sodium hydroxide was also determined for a series of oxycelluloses produced by the oxidation of soda cellulose by gaseous oxygen, and the results are given in Table V. The maximum solubility of these materials, which from their method of preparation have been swollen prior to modification occurs at an alkali concentration of about 2·75*N*, *i.e.* at a slightly higher concentration than with the modified celluloses prepared from cotton not previously swollen. As the series is ascended, the solubility at any alkali concentration increases with increasing fluidity, *i.e.* with increasing degree of oxidation. The most highly modified sample CSO5 is almost completely soluble in sodium hydroxide solutions of concentrations from 2·25 to 2·75*N*.

The variation with the alkali concentration of the solubility at –5° C. of two hydrocelluloses, MH3/B and MH4/B, prepared from mercerised cotton and alkali boiled after modification, is also included in Table V. Maximum solubility of these materials occurs in 3*N* sodium hydroxide solution. The solubility in a solution of this concentration is considerably greater than in 2·5*N* alkali, and a similar result was obtained with the same two hydrocelluloses before alkali boiling, as well as with two less modified hydrocelluloses, MH1 and MH2, similarly prepared.

Table V

Material	Fluidity	% Dissolved at —5° C.									
		Concentration of Sodium Hydroxide (normality at 18° C.)									
		1·75	2·00	2·25	2·50	2·75	3·00	3·50	4·00	5·00	6·00
Oxycellulose CSO1	22·4	2·0	4·8	7·2	10·1	11·4	6·4	3·2	1·9	0·9	—
,, CSO2	32·5	7·2	16·5	29·4	47·2	53·4	43·7	11·0	6·1	2·9	—
,, CSO3	42·0	17·7	46·5	73·9	86·1	87·7	83·4	36·7	14·9	4·6	1·6
,, CSO4	45·4	30·8	64·6	86·0	94·5	94·6	88·1	69·1	27·6	9·0	—
,, CSO5	48·9	42·6	76·5	95·6	96·4	96·6	93·9	78·9	37·1	13·7	—
Hydrocellulose MH3/B	37·9	2·4	6·4	17·4	34·7	60·3	61·8	15·4	5·9	2·5	—
,, MH4/B	45·6	—	—	31·4	58·1	84·4	94·1	43·7	—	—	—
Hydrocellulose H4	32·1	2·4	13·1	63·9	80·3	73·7	54·3	15·9	7·8	2·9	—
,, H4/B	32·4	3·0	26·0	71·3	82·6	76·3	62·1	21·1	8·5	2·3	—

The solubility curves for the oxycellulose CSO3 and the hydrocellulose MH3/B are given in Fig. 2, and compared with the curve for the hydrocellulose H4 prepared from unmercerised cotton.

(7) The Effect of an Alkali Boil on the Solubility of a Hydrocellulose at —5° C.

It has been shown by Clibbens, Geake and Ridge[6] that when a hydrocellulose is boiled with dilute (1%) sodium hydroxide solution, the fluidity of the material is little changed, but the reducing power, as measured by the

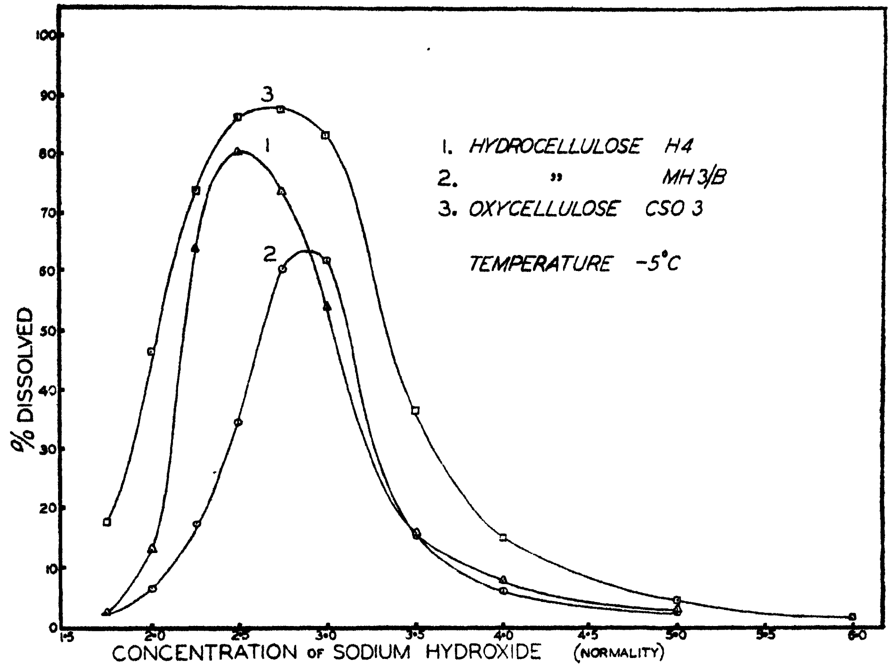

FIG. 2

copper number is diminished almost to zero. At the same time the hydrocellulose suffers a loss of weight that is proportional to the original copper number. The alkaline liquors obtained by boiling modified cotton with dilute sodium hydroxide solution are, however, very different in their properties from the solutions obtained by treating modified cotton with more concentrated alkali solutions at low temperatures. The former are dark yellow solutions from which very little material is precipitated by acidification, and which evidently contain decomposition products of the modified cellulose; the latter are colourless or very pale yellow solutions from which the dissolved material can be precipitated by acidification. Although the ultimate processes involved thus appear to be very different, it is of interest to examine the effect of the loss of material suffered during alkali boiling on the solubility of a hydrocellulose in more concentrated alkali solutions at -5° C. The data obtained with the hydrocellulose H4 before and after boiling with 2% sodium hydroxide solution under pressure are included in Table V. This hydrocellulose had originally a copper number of 2·22, which was reduced to 0·26 by the alkali boil, whilst the fluidity was changed only from 32·1 prior to the boil to 32·4 after it; at the same time there was a loss in weight of about 20%. The results given in the Table show that in spite of this loss in weight, the boiled material is slightly more soluble than the original in sodium hydroxide of all the concentrations used except 5*N*.

(8) The Effect of Pre-treatment with 5*N* Sodium Hydroxide Solution on the Solubility of Modified Cotton Cellulose in More Dilute Solutions

Birtwell, Clibbens and Geake[3] have shown that by treating modified cotton with concentrated (6 to 10*N*) sodium hydroxide solution at 15° C. and diluting the solution to 2*N* while in contact with the modified cotton, a much larger fraction is dissolved than by treatment with any single solution.

This observation suggested the investigation of similar treatment at temperatures below the normal. Experiments were made in which 1 gm. of modified cotton was treated with 50 c.c. of 5*N* sodium hydroxide, and the alkali then diluted by the rapid addition of 50 c.c. of water, giving a calculated final volume at 15° C. of 99·2 c.c. and a final concentration of 2.52*N*. The temperatures of pre-treatment with the 5*N* alkali, dilution, and final treatment with the 2·5*N* solution were varied so as to give a range of conditions. The data obtained with four modified cottons are given in Table VI. They show that pre-treatment with 5*N* sodium hydroxide solution at 15°, 0° or –5° C., followed by dilution either at the same time temperature or after reversion to 15° C. causes a decrease in the solubility at 0° or –5° C. compared with that in 2·5*N* solution without pre-treatment. With both oxycelluloses OL6/B and OL7/B, pre-treatment and dilution at 0° C. gives greater dissolution at –5° C. than pre-treatment and dilution at 15° C. or –5° C.

Table VI

Temperature (°C.)			% Dissolved			
Pre-treatment with 5*N* NaOH	Dilution to 2·5*N*	Final treatment with 2·5*N* NaOH	Oxycelluloses OL16/B	Oxycelluloses OL7/B	Oxycelluloses OL6/B	Hydro-cellulose SHL7/B
No pre-treatment		15	—	4·4	—	—
		0	28·8	60·2	—	—
		–5	50·5	85·2	97·6	94·7
15	15	–5	—	30·7	77·1	54·2
0	15	–5	—	31·0	—	—
–5	15	–5	—	27·1	—	—
0	0	0	—	50·3	—	—
0	0	–5	—	50·4	91·7	—
–5	–2*	–5	13·5	37·5	72·7	—

(* Solution at –5°, diluting water at 1° C.)

A further series of experiments was then made in which after pre-treatment with 5*N* sodium hydroxide at 15° C. and dilution of the alkali to various known concentrations, also at 15° C., the solubility was determined in the diluted alkali after cooling to –5° C. In order to separate the effect of the pre-treatment with 5*N* alkali and the dilution from that of the final low temperature treatment, it was necessary to determine the effect on the solubility of dilution from 5*N* to lower concentrations before proceeding to the determination of the solubility in the diluted solutions at –5° C. One gm. of the modified cotton was treated at 15° C. with x c.c. of 5*N* sodium hydroxide solution for 1 hour, the solution then rapidly diluted by the addition of $(100 - x)$ c.c. of water at 15° C. and the mixture kept at 15° C. for another hour. This dilution brought the alkali concentration to approximately $(5x/100)N$ and the volume of the solution to slightly less than 100 c.c. The concentration of cellulose in solution was then determined in the usual way. In a second series of experiments, after pre-treatment with 5*N* solution and dilution at 15° C. the mixtures were cooled to –5° C. before determining the solubility. The contraction produced by the mixing of the 5*N* solution and the water was calculated from data relating the composition and density of sodium hydroxide solutions, and allowance made for it in calculating the percentage of the modified cotton dissolved. The data obtained with oxycellulose OL7/B are given in Table VII and are to be compared with the data for the solubility of this material in single solutions already given in Table II.

Table VII

Oxycellulose OL7/B pre-treated with 5*N* NaOH and the Alkali diluted at 15° C. Solubility determined at 15° and —5° C.

Temperature (°C.)	% Dissolved								
	Concentration of Sodium Hydroxide Solution (normality)								
	1·51	1·76	2·02	2·27	2·52	2·77	3·02	3·27	3·52
15	13·5	17·9	22·8	23·8	19·9	15·4	10·4	7·6	5·6
−5	13·7	18·0	22·9	28·0	30·7	38·0	29·7	21·8	16·3

This comparison is shown graphically in Fig. 3. The results show that, in agreement with the findings of Birtwell, Clibbens and Geake[3], treatment with 5*N* sodium hydroxide solution at 15° C. followed by dilution to lower concentrations produces the dissolution of a larger fraction of the oxycellulose than can be dissolved by extraction with any single solution at the same temperature; maximum solubility occurs when the final concentration is between 2·0 and 2·25*N*. When, after a similar treatment, the mixtures of modified cotton and sodium hydroxide solution are cooled to −5° C. the solubility is further increased, but except at low concentrations where the dilution has already produced greater dissolution than occurs on extraction at −5° C. without pre-treatment, this solubility is much less than that obtained without pre-treatment. In this series of experiments maximum solubility occurs in 2·75*N* solution, whereas when there is no pre-treatment with 5*N* solution it occurs in 2·5*N* solution. Thus a treatment that causes swelling but not dissolution applied after modification has a similar effect

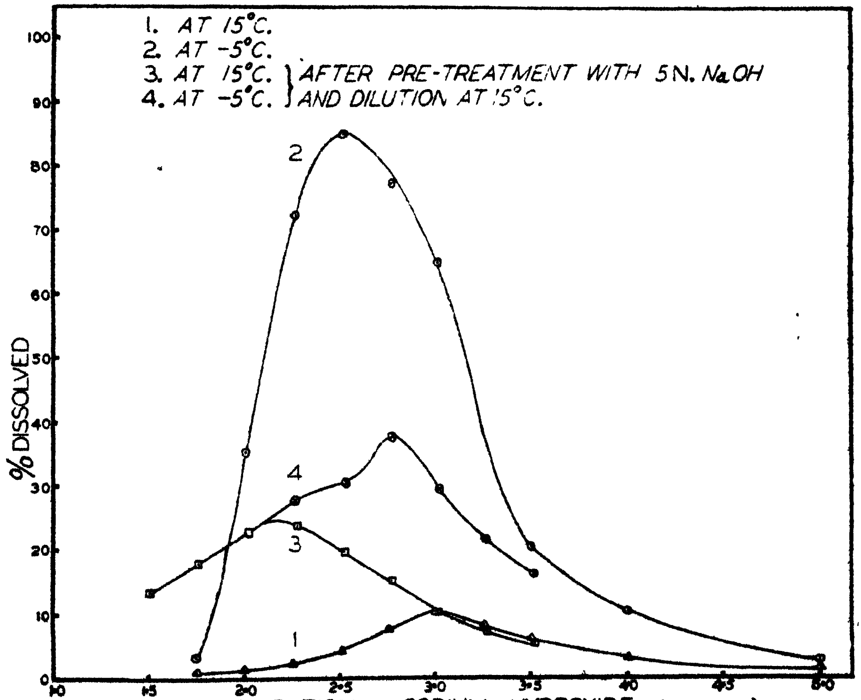

Fig. 3

on the concentration for maximum solubility to a swelling treatment applied before modification.

(9) The Effect of the Rate of Dilution on the Solubility as Determined by Treatment with 10*N* Sodium Hydroxide Solution followed by Dilution of the Alkali to 2*N*

Birtwell, Clibbens and Geake[8] have shown that the conditions for obtaining maximum solubility of a modified cotton in sodium hydroxide solution at the ordinary temperature consist in first swelling it in 10*N* solution and then diluting the alkali to about 2*N*. Neale[18] has suggested that this behaviour is due to a transient swelling, which, as he showed experimentally with regenerated cellulose sheet, occurs when a concentrated sodium hydroxide solution in equilibrium with cellulose is suddenly diluted. The explanation of this swelling put forward by Neale, which will be discussed later, leads to the conclusion that if the dilution were performed slowly instead of rapidly, the transient swelling and consequently the increase in solubility when a modified cellulose is used, would not take place. The object of the experiments now to be described was to test this conclusion.

One gm. of the modified cotton was put in a 150 c.c. bottle and steeped in 20 c.c. of 10*N* sodium hydroxide solution for 15 minutes at 15° C. In one experiment, the alkali was then rapidly diluted to approximately 2*N* by pouring in 80 c.c. of water and shaking the bottle. The mixture was then kept at 15° C., with occasional shaking, for 1 hour. In a second experiment the dilution was performed by running in the 80 c.c. of water at the rate of 5 c.c. every two minutes, with shaking after each addition. The temperature was kept at 15° C. throughout the dilution by standing the bottles containing the modified cotton and the diluting water in water maintained at that temperature. The amount of modified cellulose dissolved by the two methods was then determined in the manner already described.

Experiments were performed with two oxycelluloses and a hydrocellulose, and the results are given in Table VIII, along with the maximum solubility of the materials in a single solution at 15° C. The Table shows that in both instances the solubility produced by the slow dilution is considerably less than that produced by the rapid dilution, although it is greater than that in 3*N* sodium hydroxide solution, at which concentration the maximum effect for a single solution is obtained. The conditions in the slow dilution are by no means ideal, since with the highly swollen cotton embracing a large proportion of the volume of the mixture it is impossible to avoid running water directly on the cotton and so producing locally more rapid dilution than is intended.

Table VIII

Conditions of Extraction	% Dissolved		
	Oxycelluloses		Hydrocellulose
	OL8/B	OL7/B	H4/B
10*N*—2*N* NaOH, rapid dilution	49·4	21·8	18·5
10*N*—2*N* NaOH, slow dilution	41·0	14·2	10·9
3*N* NaOH	38·0	10·5	8·2

(10) The Relation Between the Fluidity and the Solubility of Modified Cottons

The relation between fluidity and solubility was determined for several series of modified cotton celluloses, the solubility being measured at −5° C. in the sodium hydroxide solution of maximum solvent power. As has already been seen, the alkali concentration which gives maximum solubility at this temperature varies from 2·5 to 3·0*N* according to the type of modified cotton used. The fluidities and solubilities of all the materials examined are collected in Table IX, and the relation between fluidity and solubility is shown graphically in Figs. 4 and 5.

The results show that whilst within each series of modified cottons the solubility increases with increasing fluidity, the fluidity-solubility relation differs for each class of modified cotton examined. The oxycelluloses prepared by the action of hypochlorite have the highest solubility for a given fluidity. When these oxycelluloses are alkali boiled there is a considerable rise in fluidity and also an increase in solubility, but the solubility of the boiled materials for a given fluidity is less than that of the unboiled oxycelluloses. The solubility of the hydrocelluloses prepared from cotton No. 310 is, for a given fluidity, higher than that of the hydrocelluloses prepared from cotton

Table IX

Material	Sample No.	Concentration of NaOH used	Before Alkali boiling			After Alkali Boiling		
			Fluidity	Copper Number	% Dissolved	Fluidity	Copper Number	% Dissolved
Scoured cotton, unspun	217	2·5*N*	5·9	0·08	3·5	—	—	—
	310	2·5*N*	8·0	0·16	4·3	—	—	—
Hydrocelluloses from cotton No. 217	H5	2·5*N*	15·9	0·69	15·8	16·8	0·12	21·0
	H6	2·5*N*	22·7	1·28	33·0	23·7	0·20	41·8
	H4	2·5*N*	32·1	2·22	80·3	32·4	0·26	82·6
	H7	2·5*N*	36·5	—	88·9	36·3	—	91·3
	H3	2·5*N*	42·3	—	95·9	—	—	—
	H8	2·5*N*	—	—	—	38·2	—	94·9
Hydrocelluloses from cotton No. 310	SHL1	2·5*N*	14·7	0·58	17·9	17·5	0·04	19·2
	SHL2	2·5*N*	18·0	0·85	30·1	20·3	0·08	32·5
	SHL3	2·5*N*	23·2	1·29	52·6	24·9	0·13	56·1
	SHL4	2·5*N*	25·7	1·44	65·6	27·7	0·18	70·1
	SHL5	2·5*N*	28·1	1·91	72·6	29·4	0·21	73·6
	SHL6	2·5*N*	33·0	2·64	87·5	34·0	0·31	86·0
	SHL7	2·5*N*	36·7	3·30	93·3	38·2	0·45	94·7
Scoured cotton No. 217 mercerised	217M	3·0*N*	7·2	—	1·4	16·5	—	4·3
Hydrocelluloses from mercerised cotton No. 217M	MH1	3·0*N*	21·9	—	5·8	27·0	—	17·2
	MH2	3·0*N*	29·1	—	11·7	32·8	—	32·6
	MH3	3·0*N*	35·6	—	28·3	37·9	—	61·8
	MH4	3·0*N*	44·9	—	74·5	45·6	—	94·1
Oxycelluloses from cotton No. 217 (NaOH and O_2)	CSO1	2·75*N*	22·4	0·55	11·4	—	—	—
	CSO2	2·75*N*	32·5	1·04	53·4	—	—	—
	CSO3	2·75*N*	42·0	1·58	87·7	—	—	—
	CSO4	2·75*N*	45·4	1·97	94·6	—	—	—
	CSO5	2·75*N*	48·9	2·18	96·6	—	—	—
Oxycelluloses from cotton No. 310 (NaClO)	OL13	2·5*N*	9·7	0·39	9·9	13·2	0·03	15·0
	OL14	2·5*N*	11·0	0·56	16·7	16·1	0·03	23·5
	OL15	2·5*N*	13·2	0·87	24·5	21·2	0·10	36·7
	OL16	2·5*N*	15·8	1·17	35·2	23·9	0·12	50·5
	OL11	2·5*N*	19·3	1·76	57·1	31·2	0·21	76·4
	OL7	2·5*N*	21·6	2·30	77·1	34·1	0·26	85·2
	OL12	2·5*N*	27·7	3·46	90·0	39·7	0·36	95·7
	OL8	2·5*N*	30·8	4·16	95·2	41·5	0·48	96·5
	OL9	2·5*N*	32·8	4·88	96·0	42·3	0·41	96·8
	OL10	2·5*N*	35·3	5·63	96·4	43·4	0·47	97·0
	OL6	2·5*N*	37·0	6·21	98·7	45·4	0·55	97·6

No. 217. With the hydrocelluloses, the rise of the fluidity on alkali boiling is much less than with the oxycelluloses, and the increase in solubility produced by alkali boiling is also small. For a given fluidity, the solubility of the boiled relative to that of the unboiled hydrocellulose differs somewhat in the two series examined; whilst the solubility of a boiled hydrocellulose prepared from cotton No. 310 is slightly less than that of an unboiled hydrocellulose of the same fluidity, the solubility of a boiled hydrocellulose prepared from cotton No. 217 is slightly higher than that of unboiled hydrocellulose of the same fluidity. Nevertheless, as Fig. 5 shows, the fluidity-solubility relation for the hydrocelluloses of both series, whether alkali boiled or not, could be represented approximately by a single curve, and this curve would also give approximately the fluidity-solubility relation for the oxycelluloses prepared by the action of hypochlorite and alkali boiled after modification. The most noteworthy feature of the results illustrated in Fig. 5 is the difference between the curves for hydrocelluloses prepared from unmercerised and mercerised cotton respectively; hydrocelluloses prepared from mercerised cotton are much less soluble than hydrocelluloses of the same fluidity made from unmercerised cotton. Birtwell, Clibbens and Geake[3] observed somewhat similar behaviour in their measurements of the solubility of hydrocelluloses by the $10N - 2N$ treatment at 15° C., namely that for a given copper number the solubility of hydrocelluloses made from mercerised cotton is considerably lower than that of hydrocelluloses from unmercerised cotton. The series of oxycelluloses obtained by the action of oxygen on soda cellulose have a much lower solubility for a given fluidity than the oxycelluloses of the hypochlorite series, so that here also the effect of previous swelling treatment is apparent. This effect may be compared with the observations recorded in Section II (8) which show that a treatment that causes swelling without appreciable dissolution, applied after modification, depresses the solubility in more dilute solutions at –5° C.

(11) The Separation of Modified Cotton Cellulose into Fractions of Different Fluidity

The dependence of the solubility of a modified cellulose on its fluidity suggested that when a modified cotton was separated into a soluble and an insoluble portion by means of extraction with a sodium hydroxide solution, the fractions would differ in fluidity. Further, the very marked effect of the concentration of the alkali and the temperature of extraction on the solubility made it seem probable that, by a suitable choice of these conditions, successive extractions of a modified cotton would yield any desired number of such fractions. The fractionation of a modified cellulose was therefore undertaken and for this purpose the alkali-boiled hydrocellulose H4/B, the solubility of which under various conditions was already known, was chosen. In order to separate this material into four fractions, three treatments which would dissolve increasing amounts of the hydrocellulose were necessary; the conditions of alkali concentration and temperature selected for these extractions were (1) $2{\cdot}25N$ at 0° C. (2) $2{\cdot}5N$, at 0° C. and (3) $2{\cdot}5N$ at –5° C.

Thirty gm. of the hydrocellulose of known moisture content was treated with 900 cc. of $2{\cdot}25N$ sodium hydroxide solution at 0° C. for 1 hour, and after the mixture had reverted to room temperature, the insoluble portion was separated by filtration on a Buchner funnel (without filter paper) under suction. After washing with $2{\cdot}25N$ sodium hydroxide solution on the filter, and pressing out as much of the solution as possible, the insoluble portion

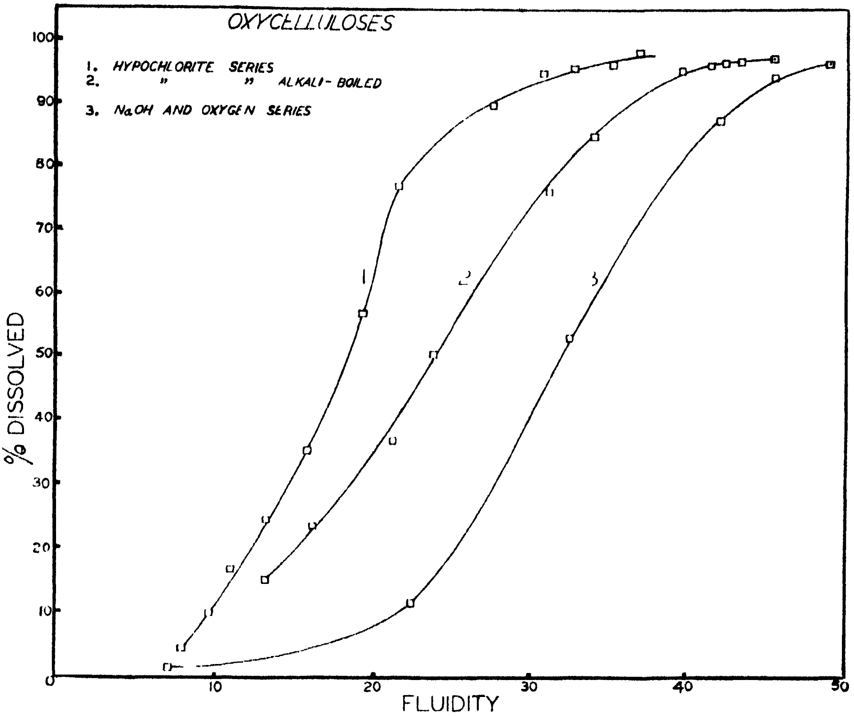
OXYCELLULOSES
1. HYPOCHLORITE SERIES
2. " " ALKALI-BOILED
3. NaOH AND OXYGEN SERIES
% DISSOLVED
0
10
20
30
40
50
60
70
80
90
100
FLUIDITY
10
20
30
40
50
1
2
3

FIG. 4

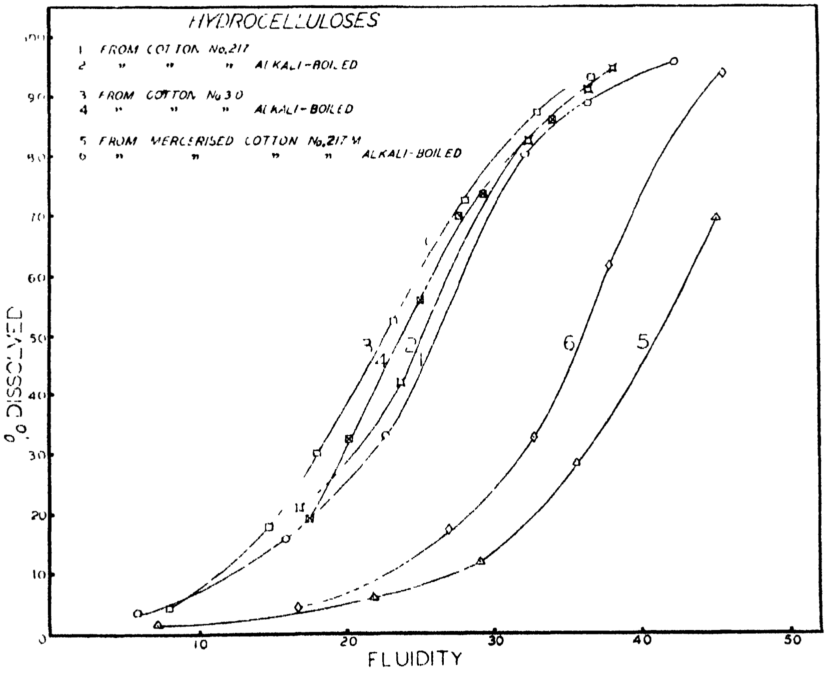
HYDROCELLULOSES
1 FROM COTTON No.217
2 " " " ALKALI-BOILED
3 FROM COTTON No 30
4 " " " ALKALI-BOILED
5 FROM MERCERISED COTTON No.217 M
6 " " " " ALKALI-BOILED
% DISSOLVED
0
10
20
30
40
50
60
70
80
90
100
FLUIDITY
10
20
30
40
50
3
4
2
1
6
5

FIG. 5

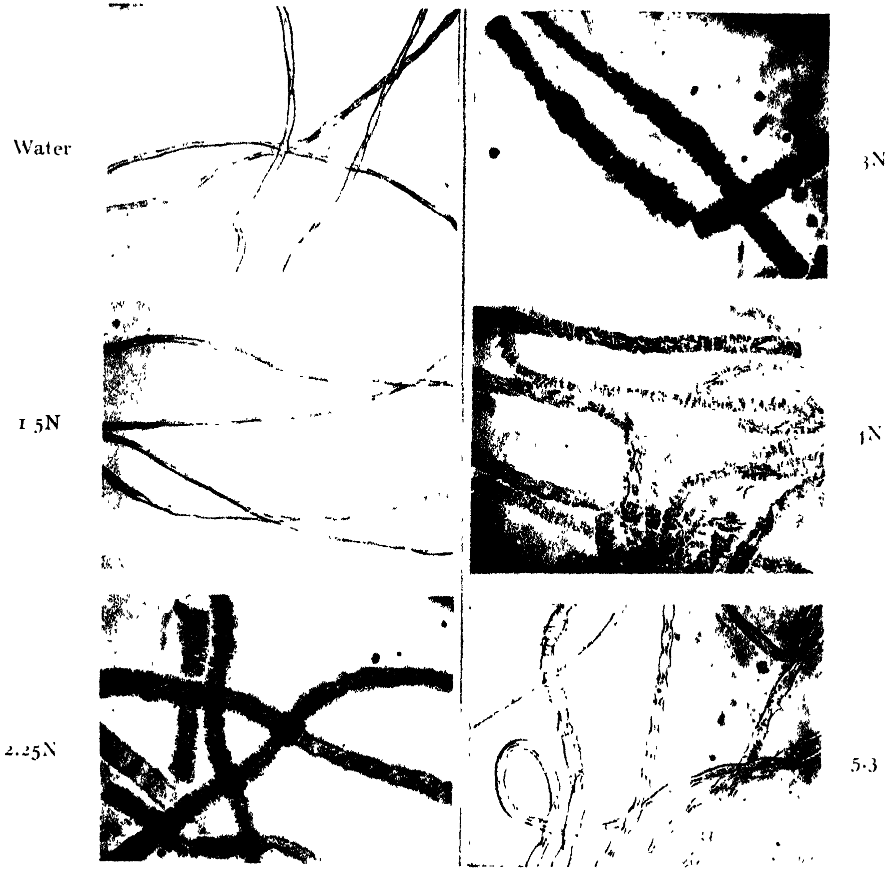

Fig. 7

Hydrocellulose after treatment at 5° C. with sodium hydroxide solution.

was washed with water, followed by $N/20$ hydrochloric acid; it was finally washed to neutrality and allowed to dry at room temperature. The filtrate, which included the solution obtained by washing off the alkali from the insoluble portion, was neutralised with acid and the precipitated modified cellulose filtered in a Jena glass filter. After being washed free from acid and salt, the regenerated hydrocellulose was dried in a vacuum desiccator over phosphorus pentoxide, and powdered. This constituted the first fraction. A weighed quantity of the insoluble portion was then extracted with $2{\cdot}5N$ sodium hydroxide solution at 0° C., and after filtering on a fritted glass filter owing to the more gelatinous nature of the undissolved portion, the two fractions were treated as in the first fractionation. The insoluble portion from this second extraction was then treated with $2{\cdot}5N$ sodium hydroxide solution at −5° C. Here it was found that the mixture was too gelatinous to filter, so it was centrifuged in stoppered tubes and the supernatant liquor taken as containing the soluble portion. The two fractions were regenerated with acid in the usual way. After each extraction, the weight and moisture content of the insoluble portion, and the weight of that part which was used as the starting material for the next extraction, were determined. From these data, it was possible to calculate the percentage of the original material in each of the four fractions.

Table X

Material	Per cent. of Original Hydrocellulose	Fluidity (2% Solution)
Original Hydrocellulose	100	6·2
1st Fraction	19	16·6
2nd „	19	10·8
3rd „	29	6·2
4th „	33	3·6
Insoluble portion after 2 fractionations, *i.e.* 3rd and 4th fractions	62	4·4
Mixture of fractions in the proportions in which they occur in original material	100	6·7

The fluidities of the four fractions were then determined by the method described by Clibbens and Geake[5], except that in order to render the measurement more sensitive, solutions in cuprammonium containing 2% instead of the usual 0·5% of cellulose were employed. Table X gives the results obtained, and shows that the four fractions differ very definitely in fluidity, the most soluble portion having a fluidity considerably higher and the least soluble portion a fluidity lower, than that of the original hydrocellulose. The fluidity of the insoluble portion after two extractions, *i.e.* the portion consisting of the third and fourth fractions, was determined, and, as shown in the Table, it had a value intermediate between those of its two constituent fractions. As a final check, fluidity determinations were made on a mixture of the four fractions in the proportions in which they occurred in the original hydrocellulose, the calculated weights of each required being introduced into the viscometer before dissolution. The fluidity found was 6·7, as against 6·2 for the original hydrocellulose.

(12) The Precipitation of Modified Cellulose from Solution

Qualitative experiments showed that if the alkali concentration of a solution of modified cellulose in $2{\cdot}5N$ sodium hydroxide solution was reduced or increased beyond certain limits by addition of water or more concentrated sodium hydroxide solution, precipitation took place. This behaviour was examined quantitatively for an alkali-boiled oxycellulose OL8/B, modified so as to be practically completely soluble in 2·5*N* sodium hydroxide solution at –5° C. The variation of the solubility at –5° C. with the concentration of the alkali solution was first determined (see Section II (5)), and it was found that at the optimum concentration of 2·5 *N*, the material was dissolved to the extent of 96·5%. A 2% solution of the oxycellulose in 2·5*N* sodium hydroxide solution was then prepared at –5° C., and after it had reverted to room temperature, it was centrifuged. By diluting 50 c.c. portions of this solution with an equal volume of water or of sodium hydroxide solutions of various concentrations, a series of mixtures containing 0·965 gm. of modified cellulose per 100 cc. and of alkali concentrations ranging from 1·25 to 5·0 *N* was obtained. In order to get mixtures of lower alkali concentration, but of the same oxycellulose content, more concentrated solutions of the oxycellulose were made, and suitably diluted with water. The bottles containing the diluted mixtures were evacuated, filled with nitrogen, and kept in a thermostat at 15° C. Preliminary experiments showed that where precipitation occurred, it was virtually complete in 10 days, so at the end of this period the concentrations of oxycellulose in the various solutions were determined. The results obtained are shown graphically in Fig. 6, and are compared with the solubilities obtained by (1) extraction of 1 gm. of the oxycellulose with 100 c.c. of sodium hydroxide solution at 15° C. for 10 days, (2) extraction at –5° C. and keeping at 15° C. for 10 days (see Section II (5)). Over the range of alkali concentration from 1·25 to 3·38*N* there was no precipitation, but outside this range there was a rapid fall in the oxycellulose concentration with decreasing and increasing alkali concentration. The

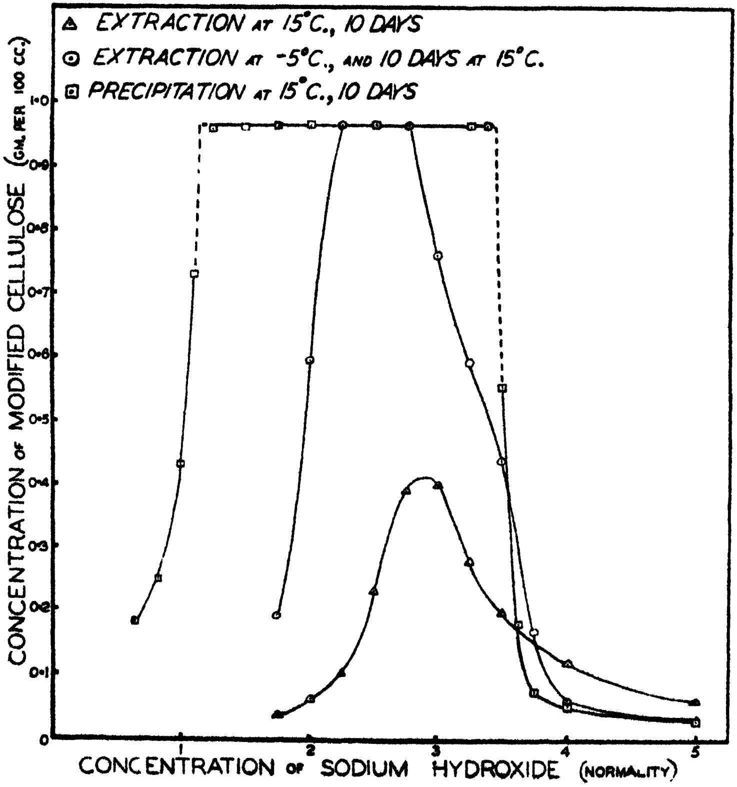

Fig. 6

figure shows that on both sides of the sodium hydroxide concentration that produces a maximum extract at –5° C. there is a region where the alkali solution can retain in solution much more modified cellulose than it can dissolve directly. At alkali concentrations above 3·6*N*, the modified cellulose concentrations attained by precipitation are definitely lower than those found by extraction at 15° C. From the absence of precipitation below the alkali concentration of 3·38*N* it might have been expected that solutions prepared by extraction at –5° C. and kept at 15° C. would not show any fall in modified cellulose concentration below a similar alkali concentration, but it has been seen that with alkali concentrations of 3·0*N* and 3·25*N* there is a slight fall. This fall becomes much more pronounced at alkali concentrations within the precipitation zone, and at alkali concentrations of 4 and 5*N*, the modified cellulose concentrations found by extraction at –5° C. and keeping at 15° C. and by the precipitation method are almost the same.

III—DISCUSSION AND THEORETICAL INTERPRETATION OF RESULTS

Within the last few years, advances along several lines of investigation have made it possible to assign to cellulose a structure that accounts in a satisfactory way for many of its peculiar properties. It is now thought that cellulose is built up of long chains of anhydro-glucose units, linked by primary valencies and held together laterally by residual valency forces. The anhydroglucose units have the Haworth pyranose ring structure[14], and are bound together by 1:4 glucosidic oxygen linkages.

Such a structure for cellulose provides an explanation of much of its chemical behaviour. When cellulose is attacked by acids, hydrolysis of the glucosidic linkages is assumed to take place, and shorter chain-molecules of various lengths are produced; at the same time, for each linkage broken an aldehydic reducing group is produced at the end of a chain. As hydrolysis proceeds, the maximum chain-length decreases and the chain-length frequency distribution alters progressively until ultimately only glucose is left. Thus a hydrocellulose is pictured as consisting of chain-molecules differing only in the number of glucose units contained in them, and each having at one end a reducing group which gives rise to the copper number. Such a material prepared from cotton has a lower tensile strength and a higher fluidity in cuprammonium than the original cotton. The fall in tensile strength is an obvious effect of the shortening of the chain-molecules, and the increase of fluidity has been generally attributed to the same cause, the extensive work of Staudinger[25] providing ample support for this view. Ridge and Turner[22] have shown that the fluidity of mixtures of unmodified cotton cellulose and a modified cellulose (scoured cotton and viscose rayon) is not a linear function of the composition of the mixture, but that there is approximately a linear relation between the percentage of rayon and the logarithm of the fluidity. It is therefore evident that fluidity is related not only to the average chain length, but also to the frequency distribution of the individual chain lengths about the average. However, in the absence of precise knowledge on this point, it will be assumed for the purpose of discussion that fluidity is determined by the average chain length.

The explanation of the properties of cotton that has suffered oxidising attack is less simple than with hydrocelluloses, since here the method of attack on the chain-molecules is largely unknown. The properties of oxycelluloses vary with the method of preparation, but there is always a fall in tensile strength and a rise in fluidity, indicating the breaking of chain-molecules. It seems probable that the glucosidic linkages are not directly attacked, but that the adjacent primary alcohol group is first oxidised to an aldehyde and then sometimes to a carboxyl group, causing either weakening or actual scission of the glucosidic linkage. The supposition that the chemical stability of the chain-molecules is sometimes diminished by oxidation without actual scission is supported by a study of the action on cotton of dichromate in acid solution[7]. This action leads to a rapid enhancement of reducing power accompanied by a very slow reduction of tensile strength, but a further considerable fall in tensile strength is produced by boiling the oxycellulose with dilute sodium hydroxide solution or even with water—treatments that are without appreciable effect on the strength of unmodified cotton and have but little effect on that of hydrocelluloses.

The hypotheses suggested to account for most of the observations recorded in this paper are (1) that cellulose acts as a very weak acid (*cf.* Neale[18]), and forms with a strong base a salt that is soluble in the alkali solution to an extent that depends on the length of the chain-molecules and on the concentration of the alkali, (2) that before dissolution of a modified cotton can take place the cohesive forces of the cellulose gel must be overcome by the swelling forces, and (3) that short chain-molecules are more easily detached from the gel and so brought into solution than long ones. According to this view, salt formation is the fundamental cause of the solubility of modified cellulose in alkaline solutions, whilst the extent of dissolution of a given material depends on the factors that determine swelling and on the frequency distribution of chain length, more particularly on the short chain end of this distribution. When a gel swells without dissolving, the limitation of the swelling may be regarded as due to the balancing of the swelling forces by the cohesion of the gel, and when dissolution succeeds swelling, this may be regarded as due to the cohesive forces being overcome by the swelling pressure. The detachment of a chain-molecule from its neighbours by the overcoming of the cohesive forces in this way is more likely to occur when the chain-molecule is short than when it is long, since the shorter the chain-molecule the greater is the probability of its becoming free at all points simultaneously. Thus, when dissolution is only partial, the dissolved material consists of shorter chain-molecules than the undissolved residue, and the shorter the chain-molecule the less is the critical degree of swelling required to disperse it into solution. Unmodified cotton does not dissolve in sodium hydroxide solution because of the great length of the chain-molecules, but if the cotton has been modified by chemical attack, all chain-molecules up to a certain length, depending on the swelling conditions, are dispersed into solution. The percentage of the modified cotton dissolved will therefore depend on the degree of modification, and therefore on the fluidity, as well as on the alkali concentration and temperature, which determine swelling.

The effect of varying the amount of modified cellulose extracted with a given volume of sodium hydroxide solution finds a simple explanation on the theory outlined above. The results recorded in Table I show that when progressively increasing amounts of a hydrocellulose are extracted with 100 c.c. of 2·5*N* sodium hydroxide at 0° C. the concentration of cellulosic material in solution is approximately proportional to the amount of hydrocellulose used, or the percentage of the available material dissolved is very nearly constant. When the smallest amount of the hydrocellulose is used, a certain proportion comprising all chain-molecules up to a certain length is dissolved; the solution is not saturated with respect to this soluble portion, however, so that when the amount of hydrocellulose extracted is increased, the same proportion of the available material is dissolved. At the higher ratios of hydrocellulose to solution employed, the percentage dissolved begins to decrease slightly, this probably indicating that the solution has become saturated with respect to the longest of the chain-molecules that have been dissolving.

The theory suggested is strongly supported by the separation of a hydrocellulose into fractions differing in fluidity by means of successive extractions with sodium hydroxide solutions under conditions that produce increasing dissolution of the material. From the very nature of their preparation, these fractions must differ considerably in solubility from the original material, although the third fraction was identical with it in fluidity. According to the theory, however, this fraction is obtained from the original hydrocellulose by the removal from the latter of the shorter chain-molecules, which comprised the earlier fractions, and of the longer chain-molecules, which remained in the insoluble residue. Thus its average chain-length, and hence its fluidity might remain the same as that of the original material, whilst its solubility—determined only by the short chain end of the distribution—would be quite different. It thus appears that any complete statement of the extent of modification of a cotton includes a chain length frequency distribution that cannot be completely described by any single value.

The separation of a hydrocellulose into fractions differing in fluidity is paralleled by similar fractionations of nitro-cellulose and cellulose acetate that have been performed by numerous investigators. The literature up to 1929 has been summarised by Duclaux[11], and further work has since been published [8, 12, 15, 16, 20, 23, 24]. The general conclusions to be drawn from the results obtained with these esters is that the fractions all have approximately the same degree of esterification, but differ in viscosity and some other physical properties. These results are explicable if the esters consist of chain-molecules of various lengths, on each of which, on the average, the same proportion of the hydroxyl groups have been esterified. The conclusions to be drawn from the work on the esters is thus in full accord with those drawn from the fractionation of chemically modified cotton cellulose.

If, as is suggested, the dissolution of modified cotton in sodium hydroxide solution is caused by the same forces that produce swelling, some similarity would be expected between the solubility relations of modified cottons and the swelling relations of cellulose in such solutions. The structure and shape of the cotton hair render exact measurements of swelling difficult, but if the shrinkage of cotton yarn is taken as a measure of swelling, the expected similarity can be demonstrated. The results of Birtwell, Clibbens, Geake and Ridge[4] on the shrinkage of cotton yarn in sodium hydroxide solutions of various concentrations and at temperatures down to −10° C. show that as the temperature is reduced, the maximum shrinkage is greater, and occurs at a lower alkali concentration. This swelling behaviour has its counterpart in the solubility results illustrated in Fig. 1. Similar swelling relations for cuprammonium rayon were found by Beadle and Stevens[2], who measured the water absorption of the rayon from sodium hydroxide solutions of various concentrations at temperatures from 40° to 0° C.

Microscopic examination of modified cottons immersed for a brief time in sodium hydroxide solutions at a low temperature confirm the correlation between solubility and swelling. Fig. 7 contains photomicrographs of a boiled hydrocellulose (fluidity, 34·0) that has been immersed in sodium hydroxide solutions of various concentrations at –5° C. and then returned to room temperature. The photographs show that the swelling is at a maximum in the concentration range 2·25 to 3·0*N*, which includes the solution of maximum solvent power at this temperature; incidentally, they also show the remarkable way in which the hairs break up during the solution process.

It has been found that solubility is very small at alkali concentrations above 4*N*, whereas swelling at these concentrations is by no means small, as Fig. 7 shows. The results found by the precipitation method (Fig. 6) suggest that this small solubility is due not so much to lack of swelling power as to the inability of the alkali solution to retain much modified cellulose in solution. The precipitation of modified cellulose from solution when the alkali concentration is increased above 4*N* is thus probably to be ascribed to the familiar effect of "salting out". A 1·75*N* sodium hydroxide solution, on the other hand, can retain a large amount of modified cellulose in solution, but can dissolve but little directly, even at –5° C. on account of its low swelling power. The precipitation that takes place at low alkali concentrations is to be attributed to increasing hydrolysis of the "sodium cellulosate". As the alkali concentration is progressively reduced and the degree of hydrolysis thus increased, a stage is reached when the longest chain-molecules present become insoluble and precipitate, and then the remainder precipitate in order of decreasing length.

The enhanced reactivity produced in cotton by mercerisation has been attributed to the sub-division of micelles or to the liberation of hydroxyl groups whose residual affinity was previously mutually satisfied. On either view, the proportion of the chain-molecules accessible to reagents is greater in mercerised than in unmercerised cotton, so that on hydrolysis by acids, for example, the chain length frequency distribution of the resulting hydrocelluloses should differ in the sense that a hydrocellulose made from mercerised cotton should be more nearly uniform as regards chain length than a hydrocellulose made from unmercerised cotton. For a given fluidity a hydrocellulose prepared from unmercerised cotton should contain a relatively large proportion of short chain-molecules, and hence should be more soluble in sodium hydroxide solution than a hydrocellulose made from mercerised cotton. As has been shown in Section II (10), this conclusion is in agreement with experiment. Unpublished work by Dr. A. Geake of this Association has shown that mercerised cotton yarn modified by acid attack suffers a considerably less decrease in tensile strength for a given increase of fluidity than unmercerised yarn, and similar results with mercerised yarn modified by hypochlorite oxidation have been found by Ridge and Bowden[21]; here a similar explanation could be given. The explanation in terms of differences of chain length frequency distribution must be regarded as tentative, however, since it has been shown that treatment with 5*N* sodium hydroxide solution after modification greatly reduces the solubility of modified cotton under the optimum conditions. Here the chain length frequency distribution cannot be altered by the preliminary treatment, so that if the effects on the solubility of swelling treatment before and after modification are related, another explanation must be sought.

It has already been pointed out that the action of hot dilute alkali on hydrocelluloses appears to be essentially different from that of cold concentrated alkali. The effect of an alkaline boil under the severe conditions employed in the present work is to cause a slight increase in the fluidity and in the solubility in sodium hydroxide solutions at low temperatures, so that the action can hardly be confined merely to decomposition and dissolution of the shorter chain-molecules. It is possible that the action of hot dilute alkali consists in the shortening of each chain-molecule by the removal from the end of a portion containing the reducing group, the very short chain-molecules containing only a few glucose units being decomposed into soluble products. It is difficult, however, to account for the large percentage loss of weight that occurs on alkali boiling, unless the portion removed from the end of each chain-molecule is a considerable fraction of the chain. The loss of weight depends on the severity of the boil, and this suggests that progressive shortening of the chain-molecules takes place, the attack being from the end originally bearing the reducing group. The shortening of each chain-molecule would tend to increase the fluidity, but the removal of the shortest as soluble products would tend to lower it, so that it is possible that the two effects might counterbalance one another in such a way that neither the average chain length, determining the fluidity, nor the proportion of short chain-molecules, determining the low temperature solubility, is greatly affected in spite of a considerable loss in weight.

The effect of alkali boiling on oxycelluloses is to reduce the copper number to a low value and to cause a loss of weight proportional to the original copper number, as with hydrocelluloses, but with certain of the oxycellulose series the fluidity is considerably increased and the tensile strength considerably reduced. The hypochlorite oxycelluloses investigated in the present work are of this type, and it has been seen that their solubility at –5° C. is also greatly increased by an alkaline boil. These effects can reasonably be explained by the assumption already discussed that the oxidation does not necessarily always result directly in the breaking of the chain-molecules, but reduces their chemical stability towards alkalis, so that during alkali boiling, in addition to the processes postulated to occur with hydrocelluloses, further chemical decomposition resulting in scission of the chains takes place. The probability of extremely complicated chemical changes occurring when modified cottons are treated with alkalis is strengthened by a study of the extensive literature on the action of alkalis and alkaline oxidising agents on the sugars.

The chemical stability of oxycelluloses towards alkalis may be so reduced that dissolution in the alkaline cuprammonium hydroxide at the ordinary temperature or treatment with concentrated sodium hydroxide solutions at normal or low temperatures might result in the scission of chain-molecules to a greater or less extent. Such an effect would evidently disturb any fundamental comparison of tensile strength, fluidity and solubility. It might account for the fact that the fluidity-tensile strength and the fluidity-solubility relations of oxy- and hydro-celluloses are substantially the same after the modified materials are alkali boiled, since it is improbable that dissolution in cuprammonium, or treatment with sodium hydroxide at low temperatures would produce further scission of chain-molecules after the relatively drastic hot alkaline treatment.

The transient swelling that takes place when concentrated alkali in equilibrium with cellulose is rapidly diluted was explained by Neale[18] in terms of his osmotic theory of swelling by the assumption that water diffuses into the cellulose phase more rapidly than alkali diffuses out, and he made the suggestion that this transient swelling might account for the increased proportion of a modified cotton dissolved by the 10*N*-2*N* treatment over that dissolved by any single solution. Hence, if by slow dilution of the concentrated alkali the departure from osmotic equilibrium is kept small, the increase of swelling, and therefore the increase of solubility, should be diminished. It has been seen that slowing down the rate of dilution has indeed this effect. Whilst this explanation seems to contain a certain measure of truth, it does not suffice to explain the results obtained with a similar pre-treatment and dilution at lower temperatures. It has been shown that a preliminary treatment of a modified cotton with 5*N* sodium hydroxide solution, which produces swelling but little dissolution, has the effect of depressing the solubility under the optimum conditions for dissolution at low temperatures. It has also been seen that mixing the modified cotton and the alkali solution at a higher temperature than that at which the solubility is to be measured reduces the solubility below that found when the solution is cooled to the required temperature before addition of the modified cotton. These phenomena are probably akin to each other, and suggest either that for a given degree of swelling greater dissolution is produced if the attainment of this swelling is sudden than if it is gradual, or that the swelling under given conditions of temperature and alkali concentration depends on the previous swelling history of the material in a way that is not understood.

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13—THE PHYSICAL PROPERTIES OF FABRICS IN RELATION TO CLOTHING*

PART I—A REVIEW OF THE LITERATURE

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INTRODUCTION

The literature on the hygienic properties of clothing is very diverse. Writers on this subject are many. The scope of their work overlaps often, is contradictory occasionally, and is usually limited by the interest of the particular writer. Each of the fabrics—linen, cotton, wool, silk, and artificial silk—has its adherents; and many consider that each fabric has a specialised part to play in the rational clothing of the body. Thus, linen may be chosen for its absorbency and the comfort and cleanliness in which it keeps the skin, wool for its warmth, silk for its attractiveness of appearance. Also, the various fabrics have properties which fit them specially for either intimate or external wear. It is the purpose of the present paper to discuss the available opinion of the function of clothing and how the body reacts towards it. A summary is made of the published methods of measurement of the physical properties of fabrics in relation to their suitability for clothing.

THE FUNCTION OF CLOTHING AND HOW THE BODY REACTS TOWARDS IT

The human body may be regarded as a delicately regulated thermostat,[1] to which heat is constantly being supplied indirectly in the form of food. The surplus heat is partly dissipated in the form of carbon dioxide and water, which are eliminated by the respiratory apparatus, and partly by the heat flow which is constantly taking place between the skin and its surroundings. The constant temperature of the body is approximately 37° C. (98·6° F.), and that of the skin approximately 33° C. (91·4° F.). Any appreciable departure from the former temperature is accompanied by a feeling of discomfort. Changes in skin temperature are beneficial, and usually invigorating. In the opinion of Prof. L. Hill,[2a] "the nerve endings in the epidermis and those deeper in the dermis, may be compared in action with thermo junctions. By sensing the difference between surface temperature and blood temperature, they produce feelings of chilliness or warmth. For example, if the body has been heated by exercise and is allowed to cool in a draught, the blood temperature is still at the higher level, while the skin temperature is rapidly reduced by evaporation of sweat, and a sensation of chilliness results. A continuous variation in the rate of cooling or of warming of the body is a necessary relief from monotony, and is a stimulant of metabolism" (by which process body matter is built up from food).

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* Issued by the Linen Industry Research Association in November 1929 as a Confidential Memoir, and now released for publication. During the interim, a number of papers have appeared and these are reviewed in an Appendix added to bring this paper up to date.

Heat is transferred from the body via the skin, by radiation, convection, and by evaporation of moisture. The heat flow is not always constant, but depends on the conditions of temperature and humidity to which the skin is exposed. As the temperature of the air increases to that of the body, the losses by radiation and convection become small, then zero, and when the temperature of the air exceeds that of the body, they are reversed in direction. In the latter case, although radiation may tend to keep the body at an abnormally high temperature, the surplus heat has still an avenue of escape in the conversion of water into water vapour and the removal of the latter from the skin. Under these circumstances the qualities of a garment worn next the skin must be such that the layer of air next the skin will be maintained in a dry condition by the ready absorbency and high moisture permeability of the fabric. This case represents conditions met with in the tropics; but it must be remembered that there is usually very little difference between the temperature of the skin and that of the air in its immediate neighbourhood, especially if much clothing is worn. So the absorbency and moisture permeability of clothing fabrics have, in all circumstances, an important effect upon the health of the body.

Apart from its function of heat elimination from the body, sweat also protects the naked skin from the sun's radiation by virtue of (1) the 580 calories of heat required for the evaporation of every gram of moisture excreted; (2) the formation on the skin of a reflecting surface; (3) the screen of water vapour it gives to the steaming body. With regard to (3), Tyndall gives the absorbing power of water vapour for radiant heat as being 72 times greater than that of dry air.

When perspiration[3] is excreted from the body of a normal individual it contains, on the average, 1 to 1·5% of total solids in water solution. The solids consist of the following ingredients, in the approximate proportions indicated—

Sodium chloride	50%
Other constituents, like phosphates, sulphates, and chlorides of magnesium, calcium, and potassium	10%
Nitrogeneous matter, chiefly urea	30%
Organic acids, supposed to be chiefly lactic acid, with possibly a little acetic acid	10%

This perspiration exhibits a weak acid reaction. Upon standing, it loses its acidic character and assumes a strong alkaline reaction. What is generally termed perspiration is really a mixture of two liquids. One of these, the "sebum", is secreted by the sebaceous gland, and is delivered into the hair follicles. The secretion is a lubricant, and is produced at a constant rate under varying conditions. Sweat is normally alkaline, but sebum is acid. The chief function of sweat is to regulate the temperature of the body. When little perspiration is formed, its properties are usually those of sebum; when sweat predominates, the mixture is alkaline.

The action of perspiration on textile fabrics is two-fold—(*a*) by reason of the bacterial growth which it promotes; (*b*) the deleterious effect of the salts which it contains. Wool is liable to become felted by prolonged contact with copious sweat which is alkaline. Over-chlorinated garments are particularly susceptible to alkaline hydrolysis, causing them to break down into holes.

Prolonged action of the sodium chloride present in sweat produces tendering in the case of cotton and silk.[4]

H. M. Vernon[5] has studied the relative degree of importance of the three factors—air temperature, air velocity, and the clothing of the subject. He experimented with his own clad and unclad body. He attributed the various degrees of "stagnancy" of the air to differences in air temperature, and various degrees of "freshness" to differences in air velocity. He determined the rate of cooling of the body between the temperatures of 99·3° F. and 98·8° F., after its temperature had been raised by the exercise of step climbing. He found that, in the unclad or lightly clad body, an air current of 100 feet per minute, as contrasted with still air, caused an extra coolness corresponding to a lowering of the air temperature by 2° F.–4° F., whilst in the warmly clothed body it corresponded to a lowering of only 1° F. He calculated that the naked body would remain in temperature equilibrium with air at a temperature of 81° F. to 83° F., whilst the warmly clad body would remain in equilibrium at 59° F. to 60° F. Hence, in order to induce cooling of the overheated body of a man engaged in heavy work, Vernon concludes "that it is of most importance to reduce the air temperature, and next in importance to reduce the clothing; whilst an increase of air velocity has little effect".

The action of sunlight and the ultra-violet rays from the sun upon the body is receiving an increasing amount of attention. The human body is screened by the horny layer of epidermis, 0·02–0·5 mm. thick, beneath which lie the living cells of the epidermis. In the naked subject these cells are exposed to the influence of light. Beneath these cells is the derma, or true skin, in which the blood circulates in capillaries. The epidermis reflects and scatters a part of the rays which fall upon it; but some of the visible rays penetrate and are absorbed by the blood beneath, warming the latter. The infra-red rays are absorbed by the least layer of water. They are caught by the wet layer of the epidermis, and only warm the blood in the dermis by conduction. The biologically active middle ultra-violet rays are largely absorbed by the epidermis, and exert their effect there. The short ultra-violet rays, which are powerful to kill microbes, fail to penetrate the horny layer, and so can only deal with surface bacteria. The skin screens itself from excessive light by its horny layer, and by pigment which, by absorbing visible and ultra-violet rays, screens the deeper cells and the blood in the derma.[6]

Tests[7] have been made on the relative protection from sunburn provided by linen, cotton, woollen, and silk fabrics. The coefficient of protection of the fabric was taken as the ratio of the time required to sunburn skin through the fabric, to the time required to produce sunburn of equal intensity upon unprotected skin. As far as possible, the weaves of the different materials used were chosen so that the spaces between the threads were of equal size in all cases. The following order of decreasing protective ratios was obtained—wool 20, silk 20, cotton 4, linen 3. These ratios hold only for the samples used in the tests, as it is not possible to obtain different materials of the same construction as regards weave, which have also the same weight and thickness. Consequently a generalisation cannot be fairly made on the basis of the above figures.

Measurements of the transmission of ultra-violet and visible radiation through linen, cotton, woollen, silk, and rayon cloths are described in the

Bureau of Standards Journal of Research.[8] The source of radiation used was a quartz mercury arc lamp. The radiation was filtered through a Corning purple glass (which absorbed wave lengths to 986Å). The visible radiation was isolated through a yellowish-green glass. By examining white and black samples of the same material, it was possible to eliminate the effect of the radiation transmitted through the openings between the individual threads, and thus determine the amount of radiation transmitted directly through the yarn.

The authors found that, comparing materials of the same weight, there is practically no difference in the amount of ultra-violet radiation transmitted through bleached samples of linen, cotton, viscose, and rayon. The natural silk is almost as transparent to solar ultra-violet radiation as bleached cotton. Comparing these results with the "protective ratio" given above, it would appear that most of the sunburn is caused by the visible rays. However, the "protective ratio" experiments were on an equal interspace basis, while the ultra-violet experiments were on an equal weight basis. The results, therefore, cannot readily be compared. In the case of dyed fabrics, those fabrics which have the largest interspaces between the yarns transmit the most radiation.

The penetration of fabrics by ultra-violet light has also been studied by Latzke,[37] as in the following abstract—Measurements of the protective action of various black and white fabrics on bacteria (*B. coli*) when light rays are allowed to penetrate the fabrics, and when rays exert their action on fabrics inoculated with the organisms, indicate that bacteria are held in a fabric by some physical force which renders difficult the removal of a large proportion by the mechanical process of washing. When the fabric is used merely as a screen for light rays, and the time of exposure is uniform, black offers greater protection to bacteria than white material. Light seems to be more effective in destroying bacteria through silk and linen than through cotton and wool.

Hill[26] gives the following desiderata of suitable clothing materials—"Clothes need to be as light as possible, permeable by air, allowing for evaporation, becoming to the least degree wet with sweat, not clinging to the skin when wet. A cellular structure produced by weaving, whether of wool, cotton, or linen, secures the conditions which give the material its warmth, compressibility, porosity, permeability, and evaporative power. Smooth, closely-woven materials, particularly starched and glazed, are unsuitable, because the air permeability is poor and the humidity is greater under such (when worn next the skin). Therefore sweating is more provoked, and muscular activity checked. Clothes act as an elastic cushion, their compressibility and elasticity being important properties in affording protection and comfort.

"The greatest error in clothing is lack of ventilation. Clothing should allow great adaptability of the body to change of temperature. It should not provoke sweating in the resting subject in still air at too low a temperature, *e.g.* at 27° C. instead of 30° C.

"The problem is to secure direct and adequate exposure to radiant energy which will allow an ample supply of cool, moving, dry air, in place of stagnant, warm, moist atmosphere."

In an article in the *Journal of the Institute of Hygiene*, 1927 (No. 87, New Series), the essential properties of clothing are given as—(1) Good insulation;

(2) sufficient porosity to allow access of air; (3) non-inflammability; (4) good absorption of moisture.

It was said wool absorbs most readily, but gives off moisture extra slowly, and so little chilling is produced. It was agreed that clothing should always be in as dry a condition as possible. But this points to the necessity for a garment which will get rid, as quickly as possible, of any moisture absorbed, and therefore the conclusions are contradictory. To provide for efficient transmission of moisture from the skin, the cloth must not only be a good absorber, but also a material which will dry quickly. It has been pointed out[9] that the wetting function of materials is not identical with the hygroscopic properties of the fibres.

Where protection from sunburn is required, white garments are best, as they reflect the most light. Thickness and closeness of weave are required to prevent penetration. As regards clothes most suitable for use in the tropics, Hill gives, as the best, open-meshed cellular linen or cotton—the skin being tanned. For the untanned skin, a garment must be worn of close enough weave to prevent penetration of the sun's rays; this must be loose to secure ventilation. A single, sun-proof, flapping white robe is the most desirable.

Gregory[10] has summarised the requirements of a fabric which will provide efficient clothing under tropical conditions as—(1) High reflective and emissive powers; (2) low transmitting power for radiant energy; (3) high moisture permeability.

Rubner[11] distinguishes "primary" properties of fibre—*i.e.* elasticity, power to absorb water vapour, ease with which wetted, amount of swelling when wetted, resistance to destruction when laundered—from "secondary" properties due to manufacture. The latter are—air content, air permeability, heat conductivity, water-holding capacity and evaporative power, radiant heat emissive power, and compressibility. Claimants for a particular system of clothing frequently base their claims on the primary properties of fibre, whereas, actually, the important properties of a garment depend almost wholly, not on the fibre, but on the mode of its manufacture. Hill says "that the same results would be obtained by wool, silk, cotton, or linen by weaving out of each a material of the same porosity and water-holding power, permeability to moving air and water vapour. Wool worn next the skin is warmer, because it is thicker than a smooth fine cotton or linen garment; weave the linen equally thick and porous, and it is as warm".

Curtis,[12] writing on "Clothing Hygiene", says that "wool is not the best textile for underwear, because, although it absorbs more moisture, it also retains it and dries more slowly. Silk," he says, "is nearly ideal, because it loses its moisture more rapidly than wool". Curtis advocates the union of cotton and wool, woven in cellular style, as the most serviceable material for underclothing.

Skin irritation is sometimes caused by textile fabrics. Cotton and linen fibres are smooth, while wool fibre is covered with imbrications comparable in appearance with those on a fir cone. This scaly covering gives the fibre its quality of rigidity and resistance to crushing strain. It also causes the fibres to "felt" together by the interlocking of the projecting edges of the scales. The smooth character of cellular linen garments is of special value to people whose skins are sensitive to irritation.

The conditions to be satisfied by clothing, from physiological and hygienic aspects, seem to be fairly definite. The opinions of different writers on the relative merits of different materials are very diverse. This is largely due to the fact that claims are often based on certain characteristics alone, whereas all must be considered together. There is obviously room for further work on the relative importance of the various properties. The physical properties, particularly of materials intended for underwear, which are capable of measurement are—(1) Transmission of heat, visible or ultra-violet rays; (2) heat-retaining properties; (3) permeability by air, *i.e.* ventilating qualities; (4) permeability by water vapour, *i.e.* ability to provide for the removal of moisture-laden air from the skin; (5) rate of wetting and amount of water held; (6) rate of drying.

HEAT TRANSMISSION THROUGH FABRICS

On reviewing the recorded work on heat transmission through fabrics, it is observed that, broadly speaking, the methods used fall into three types—

Type 1—Methods depending on the rate of cooling; or on the cooling power of a source of heat which is clothed with the fabric.

Type 2—Methods in which the sample of fabric rests on a heated plate. The transmission of heat through the fabric to air is measured by the amount of electrical energy supplied, as heat, to the plate.

Type 3—Methods in which the sample is placed between a heating and a cooling element. The transmission of heat is determined by the electrical energy supplied to the heating element.

Methods of Type 1 have been used to compare the thermal resistances and cooling powers of fabrics. Types 2 and 3 have been used to measure the conductivity of the cloth, *i.e.* the conductivity of fibre and included air.

By employing methods of Types 1 and 2, the conditions obtaining when clothing is worn on the body—*i.e.* temperatures of body and surrounding air, moisture-content of clothing, etc.—can be experimentally reproduced with more or less accuracy. Methods of the third type do not offer this advantage. Radiation and convection of air, and moisture, play an important part in the removal of heat from the body. It is therefore advisable that their influence upon heat transmission should be considered.

There is considerable variation in the values obtained by various experimenters[11, 18, 21] for the conductivity of fabrics.

The apparent lack of consistency of results is due to there being no standard test conditions, and to incompleteness of specification of the material; *i.e.* very little attention has been paid to the structure of the cloth, and to those properties which are determined by manufacture and service history. The porosity of the yarn and of the cloth are most important factors, influencing the conductivity. The thickness and porosity of a fabric at a given time depend on its service history. Some workers have sought to compare the conductivities of raw material and woven fabrics. Obviously, from the point of view of utility as clothing, there can be no comparison, as the air content of the material is the determining factor as regards insulation, and not so much the fibre. These points are referred to later in more detail.

Amongst the earliest recorded researches in heat transmission by fabrics are those of Dr. Krieger.[18] He used a water-filled cast-iron cylinder, which he covered with the material, and measured its time of fall in temperature from

60° C. to 10° C. Krieger found that when the cylinder was covered loosely the rate of cooling was less than if covered tightly with the same material. The doubling of materials gave very little increase in the heat retained.

Rubner[11] records the fact that an experimenter, Bégonie, determined what he called the "coefficient of utility" of garments. The experiment consisted in clothing a (water-filled) copper vessel with the material. The temperature of the water inside was 37° C.—*i.e.* about body temperature—and that of the atmosphere was 12° C. Bégonie measured the time taken by the arrangement to cool through 10 degrees. Neither Krieger nor Bégonie took into account the thickness, weight, or type of weave of their material.

Experiments along the same lines, but with many improvements, were made by Haven[14] in 1915. A number of iron steam pipes each 5 feet long, were clothed with samples of blanket materials. The pipes were brought to a temperature slightly below the boiling-point of water by means of a hot-water supply. The pipes were then allowed to cool, the fall in temperature being noted every 15 minutes for about nine hours. At a later date Haven improved his method by using one electrically-heated pipe, the temperature being kept constant at 100° F. The ends of the pipe were insulated against loss of heat, and three layers of the material under test were wrapped on the pipe. The quantity of heat escaping, in unit time, through the material was measured by the input of electrical energy. In order to maintain a large temperature gradient in the material, the experiments were carried out in a cold storage room. The thickness of this material was measured by a micrometer method. Some typical results are given in Table I.

Table I

Material		Average Thickness	Heat transmitted (Calories per min.)
Bare pipe ...		—	96·88
Cotton blanket ...	A	0·0585 in.	71·22
,, ,, ...	B	0·1265 in.	58·09
,, ,, ...	C	0·1080 in.	58·48
Half-cotton blanket	A	0·1100 in.	59·13
,, ,,	B	0·1395 in.	53·64
Wool blanket ...	A	0·1010 in.	61·28
,, ,, ...	B	0·1215 in.	52·87

Hill's[26] experiments with the kata-thermometer may be included here as being similar in type to the foregoing. The large bulb of the kata-thermometer was warmed up to about 70° C. by immersion in hot water. It was then dried and clothed with a finger-stall made from the fabric under test, and allowed to cool in a still-air chamber maintained at 13·4° C. The time of fall of the alcohol from the 100° F. to the 95° F. graduation on the stem, when divided into the "factor" of the thermometer, gave the cooling power of the combination in calories per square centimetre of bulb per second. The conditions of experiment were representative of body temperature (the average temperature of the range 100° F.–95° F.) and normal outdoor conditions. The results were given as percentage reduction of the cooling power of the unclad kata-thermometer caused by the covering material. This reduction was taken as a measure of the heat retaining value of the material. Some typical results are given in Table II.

Table II

Material	Still Air at 13·4° C. Cooling Power of Dry Kata. Millicals per sec.	Still Air at 13·4° C. Percentage Reduction in Cooling Power, due to presence of Cloth	Light Breeze at 5·2° C. Cooling Power of Dry Kata	Light Breeze at 5·2° C. Percentage Reduction in Cooling Power
Unclad	6·5	—	22	—
Thick knitted woollen glove ...	4·9	24·5	10	54·5
Ditto, thin rubber	4·0	38·0	7	68·0

The kata-thermometer was also used as a "wet bulb" instrument by covering the bulb with a muslin finger stall before immersion in warm water, and allowing the instrument to cool with the wet covering in position. Flack and Hill[26] made observations on the effect of wind on the cooling power of this "wet bulb" instrument, when covered with garments separated from the bulb by a wire frame. They found that the cooling power was less when surrounded by a wet garment and less still when surrounded by the same garment dry. They considered the wet kata-thermometer could be regarded as representing the perspiring body with its covering of moist underclothing. The cooling powers of the wet kata-thermometer when surrounded by different outer coats were expressed as percentages of the cooling power of the wet thermometer with no coat. In still air with knitted wool outer garment the percentage cooling powers were—dry on frame 64, wet on frame 78, wet in contact with bulb 81. Cotton twill fabric under the same conditions gave 63, 71, and 91, and muslin gave 66, 74, 91 respectively. The difference in still air between a wet and dry garment was considerable, but not so large between the different kinds of garments under the same conditions.

Experiments based on much the same principle as that of the kata-thermometer were carried out by Floyd and Baker.[15] Their apparatus consisted of an oil-filled copper cylinder containing a heating coil. This cylinder was surrounded by a calorimeter and an outer water jacket; a capsule of fabric was fitted on the cylinder, and the value of the current in the heating coil adjusted so as to maintain the temperature of the oil at 36° C. The capsule was removed, and the current adjusted so as to maintain the naked cylinder at 36° C. The "protective ratio" was taken as the ratio of the energy required to maintain the unclothed body at its normal temperature of 36° C., to that required to maintain the body at the same temperature when clad with the fabric being studied. The deviation of the conditions of this experiment from those of the human body are that, while the cloth was fitted tightly to the cylinder, clothing is fitted loosely to the body. The layer of air between the clothing and the body aids in preventing the heat of the latter from escaping. Also, the human body is covered with a film of perspiration, whereas the cylinder used by Floyd and Baker was dry.

In 1924 Sale and Hedrick[16] made experiments of the second type, in which the cloth rested on a hot plate, transmission of heat being to a conditioned atmosphere at a normal temperature. The hot plate was at body temperature, so that body conditions may be approached. They considered the problem from the point of view of transmission rather than conduction. Conduction by the actual fibres, convection of enmeshed air, and radiation were all dealt with. The apparatus used consisted of two similar heaters, each consisting of two flat copper plates. Between these plates there was an electric heating grid, which supplied heat at a measured rate to the copper plates. The two composite heating units were placed on opposite sides of, and in contact with, an insulating board. The two units being kept at the same temperature, there could be no temperature gradient through the board. A guard ring, maintained at the same temperature as the heater, prevented any loss of heat from the latter in its own plane. It was therefore possible to assume that all the heat supplied to a particular unit heater escaped from its free side. When the sample of material under test was placed in contact with that side, all the heat supplied to that heater must have been transmitted through the cloth. Readings were taken after temperature equilibrium had been attained. The thickness of the fabric was measured by thrusting a needle of known length perpendicularly through the cloth. The difference of the temperatures of the two surfaces of the sample was obtained by using one thermo-couple on the face of the hot plate, and another, opposite to this one, in the plane of the outer surface of the fabric. The fabric used throughout the tests was blanket material. Sale and Hendrick expressed their results in terms of the "thermal resistance" of the material, which was defined as "the number of degrees Centigrade temperature difference between the two surfaces of a fabric required to produce a heat flow of one calorie per second through 1,000 sq. cms. area of specimen". They deduced from the experiments that the thermal resistance was made up of one part, located at the boundary surfaces of the sample, and another part distributed throughout the medium. There is a gradual temperature slope in the medium. At the surfaces there is an abrupt drop in temperature. They showed that if

R_s = the combined thermal resistance of the two surfaces,

L = the thickness of the material,

r = thermal resistance per unit thickness of material,

then $R=R_s+rL$ where R is the thermal reistance of the material, and will be a linear function of its thickness if R_s is constant.

Working at a temperature of 51·7° C., they found values of R ranging from 3·05° C. to 8·78° C. for cotton blankets of thickness 0·25 and 0·86 cms., weight 43·2 and 53 gms. per 1,000 sq. cms., and density 0·1728 and 0·0617 gms. per c.c. respectively.

They suggested that the equation, $R=R_s+rL$, might be used to find r, the "resistivity" of the material, by taking different values of L. From the experimental evidence, the value $R_s=0{\cdot}46$ was found to hold good for all blankets tested.

Rudnick[17] also did some work on cotton blankets. He subjected them to repeated laundering processes in the laboratory, and determined the thermal resistance of the blanket from time to time, using a modified form of Sale and Hedrick's apparatus. The samples were then "napped" and the process repeated. The washing process was accompanied in all cases by a reduction in the thermal resistance. In general, this was restored on renapping. That is, the increase in porosity occasioned by the napping process is followed by a corresponding decrease in conductivity of the cloth. His results are shown in Table III.

Table IV

1	2	3	4	5	6	7	8	9
Material	Key to Figs. 1, 2, and 3	Thickness of Sample $=x$	Wt. per 100 sq cms. $=W$	Conductivity $=K$	Conductivity $\times$ Density $=Q_1$	$\frac{K}{x}$	Apparent Density $=d_a$	Porosity $=P$
		cms.	gms.					%
Wool No. 1	W1	0·068	1·20	0·000094	$1{\cdot}66 \times 10^{-5}$	0·00138	0·176	86·67
,, ,, 2	W2	0·126	2·65	0·000120	2·53	0·000952	0·21	84·1
,, Suiting	Ws	0·94	3·6	0·000118	4·51	0·001255	0·383	71·0
Unspun silk	—	—	0·12	0·000076	0·91	—	—	—
Silk No. 1	S_1	0·0194	0·578	0·000101	3·00	0·005206	0·296	80·2
,, ,, 2	S_2	0·0138	0·605	0·000111	4·87	0·00804	0·438	70·8
,, ,, 3	S_3	0·0138	0·64	0·000122	5·66	0·00884	0·464	61·0
,, (Artificial)	Sa	0·045	0·75	0·000117	1·95	0·0026	0·16	89·15
Flannelette	F	0·097	1·55	0·000131	2·09	0·00137	0·16	87·4
Cotton (woven)	Cw	0·030	1·0	0·000168	5·60	0·0056	0·3	77·8
,, (knit)	Ck	0·079	1·94	0·000184	4·52	0·00232	0·245	83·68
Linen (mesh)	Lm	0·098	2·6	0·000158	4·19	0·001612	0·265	82·35
,, (woven)	Lw	0·033	1·95	0·000167	9·87	0·00506	0·59	60·7

Table III

Treatment	Thermal Resistance	Treatment	Thermal Resistance
Original fabric ...	100	3rd wash ...	96
1st wash ...	97	3rd nap ...	101
1st nap ...	103	4th wash ...	92
2nd wash ...	94	4th nap ...	101
2nd nap ...	100		

The thermal resistance of cloth has been measured by Griffiths and Kaye,[18] using a method in which the sample was placed between electrically heated and water-cooled surfaces, the material being under pressure. They did not consider contact resistances at the surfaces as having any separate significance apart from the resistance of the material itself. Before testing a sample, its thickness was measured under a series of pressures, so that the thickness of the cloth under the pressure used in any conductivity experiment could be calculated. Experimenting with superposed layers of cloth, it was found that the conductivity of waterproofed silk increased considerably as the number of layers was increased. They gave the conductivities of cotton and silk as 0·00018–0·0002 and 0·0001–0·00012, respectively; the mean temperature of the cloth being 40° C., and the pressure 21 lb. per sq. cm. No further specification of the material used in the tests is given. The results are in agreement with those given by Rood[21] for knitted cotton and silks, "Nos. 1, 2, and 3" (Table IV).

The properties of cotton cloth with respect to radiant heat have been examined by Gregory.[10] In addition to direct transmission by conduction, convection of air, and passage of radiation through the air spaces, multiple internal and external reflections from the walls of the fibres have to be considered. The fabric, under controlled conditions of temperature and humidity, was subjected to a stream of radiant heat from a tubular electric furnace. The transmitted or reflected radiation was received by an exploring thermopile. It was found that the most transparent allowed about five times as much heat to pass as the least transparent, this being due to differences in the weave of the fabrics. The effect of the moisture content of the fabric upon its transmitting and reflecting qualities was studied, and it was found that a moist fabric transmitted less radiant heat than a dry one. The percentage decrease on the figure obtained for transmission when cloth was dry, increased as the saturated condition was approached. In dealing with the heat reflected from fabrics in moist atmosphere, no definite result transpired, as it was found that the maximum change in the intensity of the reflected radiation was only slightly greater than the experimental error.

The Lees "disc" method was used by Staff[19] to study the thermal conductivity of wool and cotton fabrics, with special reference to the effect of moisture content of material. Measurements were made close to room temperature with samples of varying moisture contents. He observed a fairly linear relation between conductivity and moisture, the latter measured as percentage of dry weight. The increases in conductivity noted for different samples of wool were $2\cdot0\times10^{-6}$, $1\cdot7\times10^{-6}$, and $1\cdot9\times10^{-6}$, for an increase in moisture of 1% of the dry weight. Two samples of cotton showed increases in conductivity of $3\cdot9\times10^{-6}$ and 4×10^{-6}.

The effect of the moisture content of a fabric upon its conductivity was also studied by Rood,[21] using the Lees disc method. The increase in conductivity found for an increase in moisture of 1% of the dry weight were

$1{\cdot}5 \times 10{\cdot}6^{-6}$ and $1{\cdot}37 \times 10^{-6}$ for wool fabrics and $4{\cdot}0 \times 10^{-6}$ for a cotton fabric, which are in fair agreement with Staff. Expressed as per cent. increase in conductivity per 1% increase in moisture content, the values become 1·61, 1·47, and 2·16 respectively. Rood[21] also determined the conductivities of unspun silk and a number of wearing materials, as shown in Table IV.

The knitted materials and the cotton cloth had been laundered many times in service; the others were new. Generally several thicknesses were used, the edges being sewed together and shellaced. The temperature of the samples ranged between 30° C. and 40° C. The samples were subject to a pressure of 6 gms. per sq. cm., determined by the discs. This pressure also influences the measurement of density. The results recorded by Rood are given in columns 3, 4, 5, and 6 of Table IV. The quantity "conductivity × density" (column 6) is referred to by Rood as the "conductivity per equal weight". It represents the quantity of heat flowing through such a thickness of cloth as would contain 1 gm. of material—area, time of flow, and temperature gradient being unity as specified by the definition of conductivity. By the term "density" is obviously meant apparent density, which has been determined from the weight and the thickness measurement.

Rood's conclusions were—"The woollen materials show plainly the effect of loose texture in increasing warmth, where wind is not a factor. This is shown strikingly in column 6. The silk materials show this even more so, there being an approximate linear relation between Q_1 and density." The possibility of estimating closely the conductivity where the density is known was suggested. "At equal density the substances would come in the order—silk, wool, artificial silk, linen, and cotton as to conductivity; and that, of the materials examined, unspun silk is the warmest and woven linen the coolest. The linen changes place with the cotton, because of its actual greater density in manufacture."

Rood has considered two methods of comparison of the heat transmission by different fabrics; but there are other possible methods, and, as her published results contain the requisite data, they have been reconsidered in detail by the authors, as will be described. The additional figures calculated for this purpose are shown in columns 2, 7, 8, and 9 of Table IV.

Consider the standard formula for conductivity—

$$K = \frac{Qx}{At\,(\varnothing_1 - \varnothing_2)} \quad \dots\dots\dots\dots \quad (1)$$

where Q is the quantity of heat flowing through the specimen of area A sq. cms. and thickness x cms. in t seconds, when the temperature gradient is $\frac{\varnothing_1 - \varnothing_2}{x}$. When the specimen is a unit cube, and the temperature gradient is unity, the heat flowing per second is the conductivity of the material (K). If W is the weight of a piece of fabric of area A, thickness x, and apparent density d_a—

$$W = Ad_a x \quad \dots\dots\dots\dots \quad (2)$$

therefore the thickness which will contain 1 gm. of material, per unit area, is equal to $\frac{1}{d_a}$ Substituting this value for x in (1), and considering $t = 1$, and $\varnothing_1 - \varnothing_2 = 1$, we get the quantity of heat flowing $(Q_1) = Kd_a$, which is the figure given by Rood in Table IV, column 6.

If follows from equation (1) that the heat flow per unit area, per unit time, per unit temperature difference between the two sides, is equal $\frac{K}{x}$, which is the heat flow through the specimen as actually measured (Q_3). This has been calculated, and is shown in column 7.

In column 8, "d_a", the apparent density of the cloth, has been calculated according to equation 2 from columns 3 and 4. In column 9 the porosity ("P") is given, and represents the percentage volume of air in the cloth. It was calculated from the formula of Matthew$_{22}$—

$$P=(1-\frac{da}{d_a}) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where d_0 is the absolute density of the fibre. The values of d_0 taken for the various fibres were representative of various authorities.

There are three possible bases of comparison of the thermal properties of the fabrics—

(1) The heat flowing per unit area, per second, per unit difference of temperature on the two sides, through such a thickness as will contain 1 gm. of material$=$K. $d_a=Q_1$ say.

(2) The heat flowing, under the same conditions, through 1 cm. thickness of sample$=K=Q_2$ say.

(3) The heat flowing, under the same conditions, through the actual thickness of the test piece $=\frac{K}{x}=Q_3$ say.

Methods 1 and 2 involve large extrapolations on unverified assumptions, and refer to impossible materials. Method 3 is the value given by the actual specimen. Many investigators compare such values in terms of the nature of the fibre of which the material is composed. Actually, a large proportion of a fabric consists of air, and some account should be taken of the fabric structure. The structures of fabrics may be compared in several ways—in terms of weight per unit area ($=d_a x$); thickness (x); apparent density (d_a); porosity (P). We have taken Rood's results, and examined them in relation to these various structural terms. The figures quoted in Table IV are shown graphically in Figs. 1 and 2.

No relations were apparent on plotting Q_2 (or conductivity) separately against thickness, weight, apparent density, or porosity.

Fig. 1 illustrates Rood's basis of comparison, Q_1. No relationships which include all the fabrics are apparent in (*a*) and (*b*). In Fig. 1 (*c*) the points tend to become grouped about a straight line. This effect is more marked if only fabrics made from the same fibre are considered. In Fig. 1 (*d*) this is also true, and the results for all the fabrics lie fairly close to one straight line. This, as Rood pointed out, suggests a possible connection between Q_1 and apparent density or porosity.

Fig. 2 illustrates the quantity of heat flowing through the actual thickness of the fabric (Q_3) plotted against the variables concerned. In Fig. 2 (*a*), where heat flow is plotted against thickness, the results assume a more systematic grouping than in Fig. 1 (*a*). The results from all the fabrics now lie fairly close to a single curve of hyperbolic type. In Fig. 2 (*b*) a similar, but not so marked, effect is shown for the weight per unit area. Both these graphs show that, under given conditions, there is less heat flow through thicker or heavier fabrics, and explains why heavier or thicker garments are worn in winter than in summer.

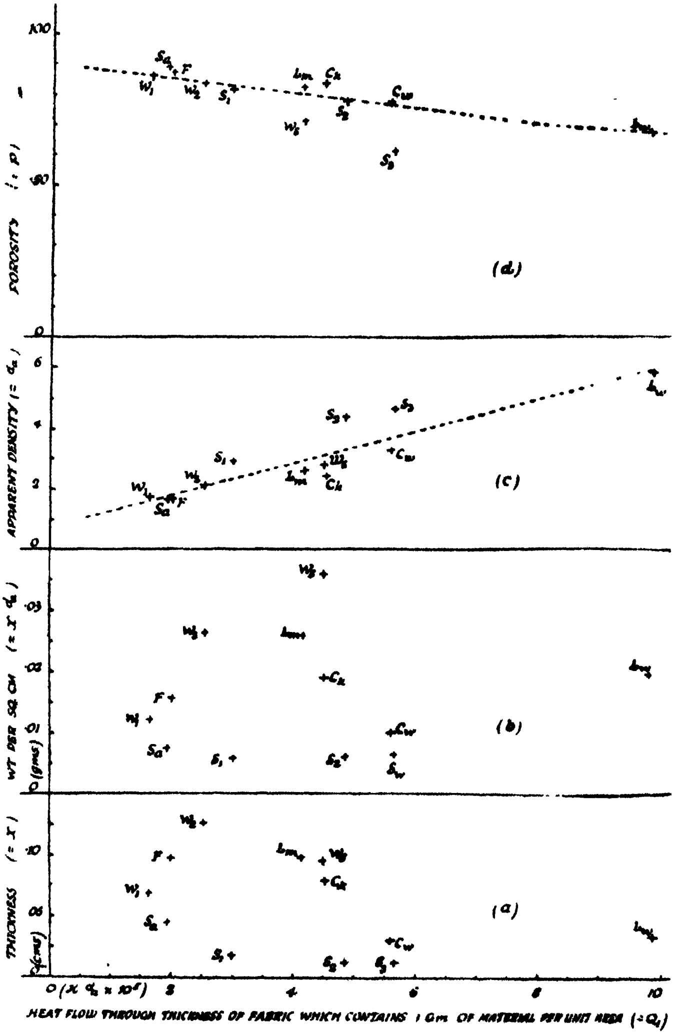

FIG. 1

In Fig. 2 (*c*) apparent density includes both the terms weight and thickness (equation 2), but not the density of the fibre. There is a linear relation between heat flow (Q_3) and apparent density, except for the woven linen sample.

Fig. 2 (*d*) shows Q_3 plotted against the porosity of the fabric. All the points lie evenly distributed about a straight line. The calculated values for porosity depend on the measured thickness of the fabric, which was stated by Rood to be subject to some possible uncertainty, which may account for the few larger departures. The porosity figure is related to the apparent and absolute densities of the fabric (see equation 3), and is therefore related both to the weight of the fabric per unit area and to the thickness (by equation 2). This explains the result, as approximate relationships between Q_s and weight

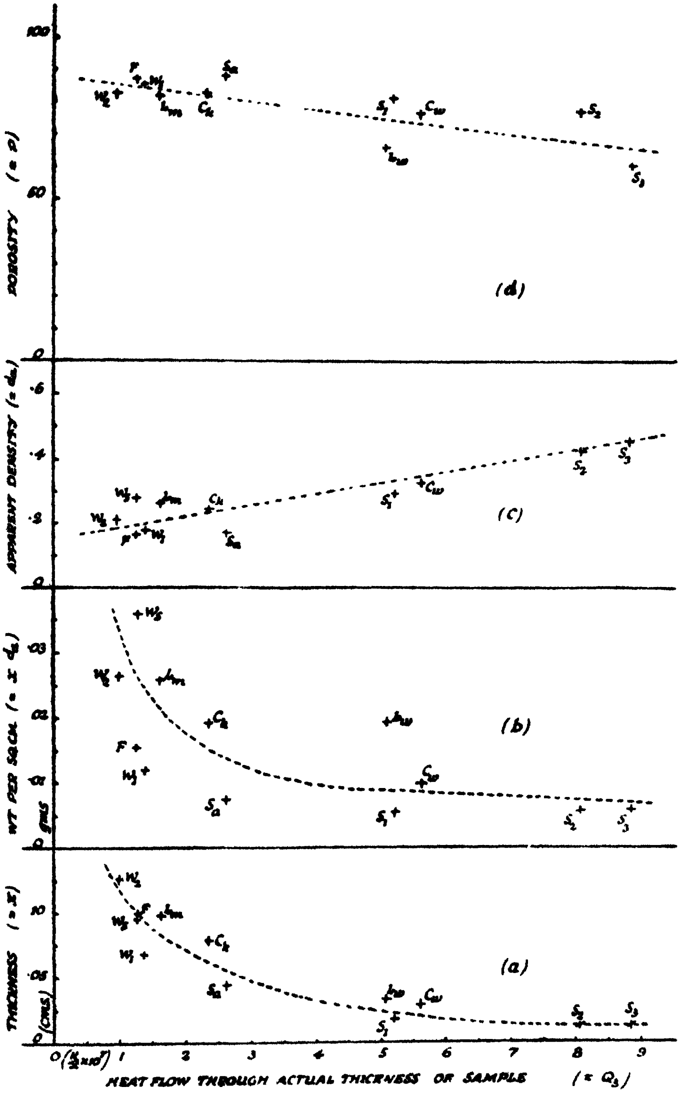

FIG. 2

and thickness are indicated in Figs. 2 (*a*) and 2 (*b*), and Fig. 2 (*c*) is a combination of these two. It would be concluded from this that, under the experimental conditions used, the actual heat flow through fabrics of different materials and construction is directly related to the porosity of the material, and is practically independent of the nature of the material.

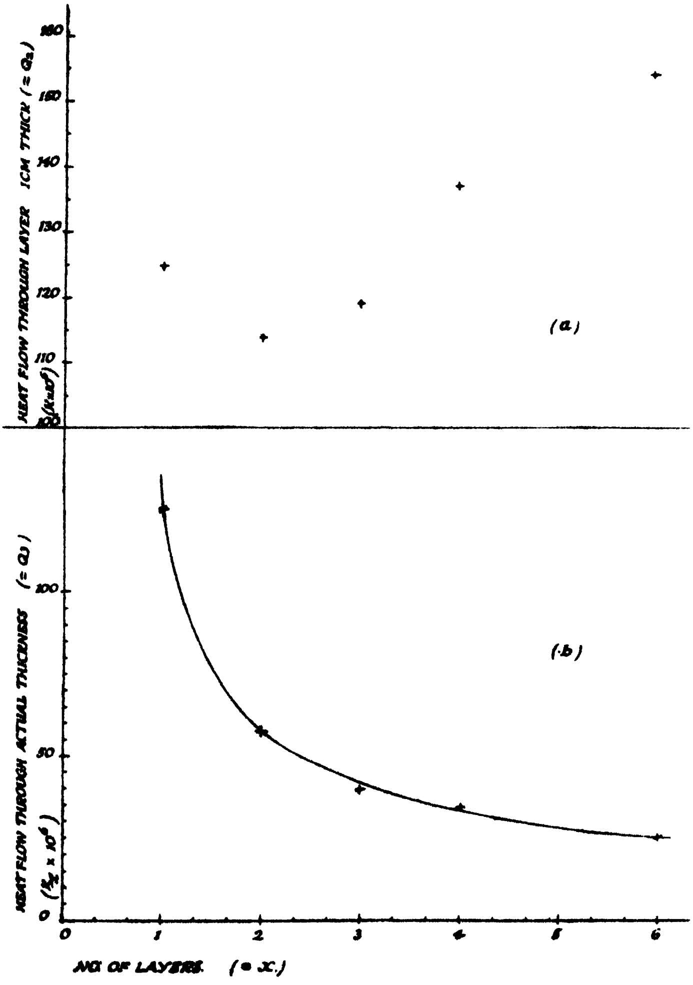

FIG. 3

Rood considered the conductivity of the wool suiting sample in more detail, directly measuring the effect of thickness by using varying number of layers. The results of this experiment are shown in Fig. 3.

These figures again show how the use of the quantity K/x brings out the relation between heat transmission and thickness in the same way as was found above for the different fabrics. The figures also show the inadvisability of extrapolating from the transmission through actual sample thickness to that through a hypothetical thickness of 1 cm., as is done to obtain "Q_2". Ten-and-a-half layers of wool suiting would be required to give a thickness of 1 cm. Roughly, three layers of wool suiting would be required to weigh 1 gm. per unit of area. That is, to obtain the quantity Q_1, the heat flow through three layers is used.

These remarks show that, in comparing the heat-retaining properties of a number of different materials, the value of heat flow through the actual sample thickness is the most suitable criterion, and this is simply related to the porosity (see Fig. 2 (*d*)). That is, the insulating value of any cloth, irrespective of the fibre employed, might be adjusted to any desired value by suitably adjusting the porosity in manufacture by variation of its structure. The essential difference in the three methods of estimating the heat transmission is in the conditions of temperature gradient; Q_3 is the heat flow through the actual fabric, with a difference of temperature of one degree between the two sides. This, we find, is related to porosity independent of the nature of the material, and is capable of direct consideration in relation to behaviour under practical conditions similar to these experimental conditions where the fabric is compressed between two bodies.

AIR PERMEABILITY

The hygienic necessity for ventilation in wearing apparel has already been discussed (see Section I). The amount of ventilation allowed by a particular garment will depend partly on the looseness of its fit and partly upon its permeability to air or wind. This quality is closely related to the porosity of the material.

Ritchie,[23] in his paper on the permeability of airship fabrics to hydrogen, described a three-fold process of fluid-flow through fabrics. When the apertures in the fabric are of molecular dimensions, the process is one of ***diffusion***, *i.e.* each gas goes through independently, at a rate proportional to the difference between its partial pressures on the two sides, and inversely as the square root of its density. The process is one of ***effusion*** when the thickness of the solid is very small. When the solid is thick the apertures can be considered as tubes of relatively great length. The phenomenon is called ***transpiration***, and the viscosity of the fluid is a factor determining the rate of transpiration.

The permeability of balloon fabrics to hydrogen was also investigated by Dr. Guy Barr.[24] He measured the rate of increase of concentration of hydrogen on the low-pressure side of the fabric—hydrogen being the gas on the high-pressure side.

In the experiments of Ritchie and Barr the gas on the high-pressure side of the test specimen was allowed to escape. The amount which passed through the specimen did so by virtue of the partial pressure difference. In the experiments about to be described, all the gas supplied is either forced or sucked through the specimen, and the volume passing through in a given time measured. In general, the permeability of a fabric to air is defined as the quantity of air which will pass through a known area of cloth of definite thickness in a definite time, when there is a known pressure difference on the two sides of the cloth, the experiment being carried out under arbitrary conditions of temperature and humidity of air.

Howe and Hudson[25] forced air through ceramic materials, using a compressor and a large tank to absorb the surge of pressure. The pressure difference used was 2 inches of water. They measured the rate of flow of air by passing the stream through standard orifices and using a differential gauge. From this, and the dimensions of the apparatus and test specimen, the permeability was obtained directly.

The "relative porosities" of different materials may be found by permeability methods. Wilson and Lines[26] compared the porosities of leather goods defining the term as the number of c.c.'s of air passed through 1 sq. cm. of leather per minute when the pressure difference taken was 12·5 cm. of mercury. The air was drawn (by a vacuum pump) through the sample from two aspirator bottles, the amount of water drawn from one bottle into the other giving the volume of air drawn through the leather.

The earliest permeability measurements on clothing fabrics would seem to be those made by Rubner.[11] He measured the number of seconds taken to force one cubic centimetre of air through 1 sq. cm. of cloth with a pressure equal to 0·42 mm. of water. He calculated his results for 1 cm. thickness of material, and obtained for dressed linen, linen mesh (free from dressing), thick cotton, and knitted stocking, 171·0, 17·2, 76·0, and 15·7 seconds respectively.

These figures may afford a fair comparison of the permeability of the samples of cloth used by Rubner in his experiments. Nothing can be deduced, however, about the permeabilities of linen, cotton, and wool, in general, from these figures, as there is no specification of the materials. Further, it does not appear sound to extrapolate for a thickness of 1 cm. when the thickness of the cloth does not often amount to one-tenth of this.

A much more recent research on the subject was that of Sale and Hedrick.[16] In their experiments the fabric, under slight tension, was pressed against the open end of a cylindrical chamber to form a practically airtight junction. Conditioned air was drawn by an aspirator through the specimen, the cylinder, and a damp gas meter, in the order mentioned. The pressure outside the cylinder was that of the atmosphere; the pressure inside was indicated by a manometer. Rate of flow readings were taken from time to time, and the volume of air passing through the sample in a given time calculated. They found that there was a critical pressure difference for each fabric, below which it was essential to work if constant values of permeability were to be obtained. The following standard conditions were adopted—

(1) A definite tension of fabric was always used.

(2) Air from the room, maintained at 70° F. and at a relative humidity of 65% was used.

(3) Eddies of air in the cylinder were avoided by having the intake to cover the entire cross-section, and a fine wire mesh partition introduced in the cross-section just preceding the outlet.

The results of tests upon blanket materials ranged from permeabilities of 0·00514 to 0·0294 litres per sec. per 1,000 sq. cms. per 1 mm. of water pressure.

WATER VAPOUR PERMEABILITY, ABSORBENCY, DRYING

We have seen that if the thermostatic condition of the body is to be maintained, the layer of air next the skin must be kept as dry as possible. This permits of that ready evaporation of moisture from the skin which is a natural outlet for excess of body heat. This is especially important if the temperature of the surroundings is high. Whether or not a fabric will maintain this condition, depends on its permeability to water vapour as well as on its air-ventilating ability. Transference of water vapour from the skin is by diffusion through the clothes, and by convection currents escaping at such openings as neck and sleeves.

Water Vapour Permeability

Hill[26] did some experiments upon this subject. As his first method, he placed a weighed amount of concentrated sulphuric acid in a dish, covering the latter with a layer of the fabric under test. After an interval of time the sulphuric acid was reweighed. The addition in weight found was due to the amount of moisture which had passed through the cloth in the given time. In this manner the permeabilities to moisture of a number of cloths were compared. The second method he employed was to find, by weight, the rate of escape of water vapour from a dish of water covered by a piece of cloth. In the first method, the diffusion of water vapour took place from a normally conditioned atmosphere on one side of the cloth up to perfectly dry atmosphere on the other. In the second method, diffusion was from a saturated atmosphere to a normally conditioned one. The results from these experiments are given in Table V.

Table V

Material	Weight of Water taken up in 21 hours (1st method) gm.	Weight of Water lost in 21 hours (2nd method) gm.
Cellular cotton ...	3·601	5·648
Flannel	3·160	5·893
Cotton shirting (1) ...	3·234	6·385
,, ,, (2) ...	3·467	5·799
,, ,, (3) ...	3·731	5·561

Hill drew the conclusion from these figures "that all the materials allowed the passage of vapour with equal ease". The difference in the value given by the two methods can be explained in terms of the difference in driving force (humidity gradient) through the fabric. In the second method the gradient is the difference between saturation pressure and the pressure of aqueous vapour in the normally conditioned atmosphere (usually about 50% R.H.), divided by the thickness of the cloth. In the first method the gradient in the cloth is very small; the greater part of the humidity gradient lies between the inside surface of the cloth and the surface of the liquid. A particle of moisture which has passed, by diffusion, through the cloth does not encounter a layer of dry air until it reaches the surface of the acid. These facts explain the higher values obtained by the second method.

Experiments on this subject were also carried out by Sale and Hedrick,[16] under conditions which were meant to approach the conditions of a garment worn on the body. They measured the rate of escape of water vapour from water at 100° F. (approximately blood heat), through the specimen, to conditioned still air outside, the latter being of 65% relative humidity. The method of test consisted in measuring, by weight, the rate of escape of water vapour from water in a glass jar covered with one layer of fabric. The water in the jar was maintained at the desired temperature by having the latter placed in a water bath whose temperature was controlled electrically to 2° F. The sample was fastened over the mouth of the jar by rubber cement, no definite tension of cloth being used. Usually ten such jars were placed in the bath, and an eleventh (uncovered) jar having an equal amount of water in it was included for control purposes The rate of evaporation was measured by removing the jars and weighing at the end of measured intervals of time. In from two to three hours this rate was found to become constant to 5 per cent. The average of two tests was taken, the surfaces of the specimens being reversed in the second test.

Somewhat similar measurements have been made for materials other than textiles, *e.g.* Martley[27] for wood, Wilson and Lines[26] for leather, and Anderson[28] for concrete.

Absorbency

Textile fabrics may contain moisture in different ways—

(1) Hygroscopic moisture, which is absorbed naturally if the fabric is dried and, placed in a humid atmosphere. The amount of water absorbed varies with the humidity and temperature of the air. All textiles behave in this way in varying degrees. The subject is very complex and cannot be briefly summarised. It has been investigated in very great detail by a number of workers, including Urquhart and Williams, by whom also some of the published work has been briefly reviewed.[36]

Two factors have to be considered in any practical use of this property—the amount of moisture finally absorbed when left in an atmosphere long enough to obtain its equilibrium or final value; and the rate at which the absorption takes place. Data in these connections for cotton, linen, wool, and silk are discussed by Parker, R. G., and Jackman, D. N.[35] At any atmospheric condition wool finally absorbs more moisture than linen, which absorbs more than cotton; but both linen and cotton absorb their moisture quickly, whereas wool absorbs its moisture very slowly.

(2) Water is also absorbed in another manner when a piece of fabric is immersed in water or placed in contact with a wet surface. In this case the fibres absorb water until they contain as much moisture as they would absorb in a saturated atmosphere; but the fibrous structure will hold considerably more than this, as the spaces between the fibres or between the yarns may become filled with excess water. Water so held is described as being mechanically held, and, obviously, the amount will depend on the pressure applied and on the structure of the fabric, apart from differences in the nature of the fibre. Here again there are two factors of importance to be considered in connection with practical use of this property, viz. the total amount of water so held, and the rate at which wetting takes place.

The term absorbency is used very commonly when writing about these four factors. In its proper place, any single one of the four may be of predominating importance, so it would be better if there was a recognised distinctive term for each, in order to save confusion. The hygroscopic moisture absorbed from the surrounding atmosphere has been called "sorbed", absorption indicating an increase and desorption a decrease in its amount. In line with these terms, "rate of sorption" would indicate the rapidity of change of sorbed moisture on change from air of one humidity to that of the other.

The water mechanically held in the interstices between fibres and yarns may be briefly described "water held"; rate of wetting and rate of drying indicating the rapidity of increase or decrease.

There is no established relation between sorbed moisture and the value of the material for clothing purposes. Barker[34] and others[29, 36] have claimed some advantage for wool on account of its high sorption, coupled with the fact that wool heats up during sorption (cotton and linen, however, also heat up to a less extent on wetting). The rate of sorption is, however, very slow for wool (and silk); whereas, in the first place, a garment is only worn for a few hours; and, secondly, we are told that the clothing should be capable of reacting quickly to changes in the conditions on and surrounding the skin. It is, we consider, more probable that the second method of holding water is of more importance in connection with underwear, particularly when the body is overheated and the skin becomes wet with sweat. The clothing should be able to absorb enough moisture to keep the skin dry. In this connection wool is notoriously at a disadvantage, as its hairy nature prevents intimate contact between the moisture and the material, and so makes wetting slow; whereas bleached linen and cotton materials wet out very rapidly.

Published figures for the amount of water held by various fabrics are not very extensive. Rouget de Lisle[32] soaked various fabrics in water, and determined the weight of water held by 100 gms. of material after wringing out by hand, by machine, and centrifuging. Similar experiments are recorded by Rubner[11] and, later, by Roaf[26] and Faber and Hadden.[9]

Faber and Hadden also examined the rate of wetting by placing the fabric in contact with saturated filter paper. The amount of water absorbed in a given time was determined by weighing. Here the comparison was by weight. Porosity or fabric structure was not considered. Their results expressed as the amount of water absorbed per gram of cloth in 20 minutes, are shown in Table VI.

Table VI

Material	Water absorbed
Silk, knitted	2·31 milligrams
Wool, similar knit	0·02 ,,
Cotton, similar knit	2·73 ,,
Linen, pentagonal open mesh	1·71 ,,
Birdseye, loose cotton twill (diaper material)	2·40 ,,
Canton, lighter twill, napped	2·46 ,,

Obviously the structure of the material must have great influence on the result, and in no case is sufficient specification given to enable any close comparison of the relative effect due to the fibre alone.

Drying

It has been pointed out that cloths can contain moisture under two different circumstances—

(1) "Water held" in the interspaces between the yarns;

(2) "Sorbed" moisture contained in the capillaries of the fibres themselves. The vapour pressure of the water in condition (1) is equal to that of water in bulk. The vapour pressure in condition (2) is less than this, due to the fact

that the vapour pressure of a liquid is less at a curved meniscus than at a plain surface.

The rate at which water will evaporate from the surface of a wet cloth at a given temperature depends on how quickly the layer of saturated vapour, which is always present at a water surface, can get away. In still air this depends on the driving force provided by the humidity gradient in the air in the immediate neighbourhood of the water surface. The equation given by Fisher[30] to represent this condition is—

$$\frac{-dW}{dt}=k\,(p_0-p_1)$$

where p_0=the vapour pressure of the evaporating water; p_1=pressure of water in the air; k is a function of air velocity; dW is the weight of water evaporated in the small interval of time (dt).

When only sorbed moisture is present—*i.e.* when the capillaries only, and not the interspaces, are filled—the rate of evaporation is not constant, but decreases, and is approximately proportional to the liquid content. The smaller the amount of "sorbed" water present, the greater the relative lowering of the vapour pressure.

In the case where wetting is not complete, but some of the interspaces are filled as well as the capillaries, the rate of evaporation from the surface of the wet material is to the rate from the surface of free water as the area of wetted surface is to that of the whole. This was pointed out by Lewis, McAdams, and Adams.[31] A complicating factor is that the heat necessary for evaporation comes from the air, and the area available for evaporation is not as great as that available for heat pick-up. The temperature assumed by the evaporating water is determined by the balance between the heat inflow and heat consumption by evaporation. As the partially wet material dries, the ratio of the surface of evaporation to that available for heat pick-up is decreased. Hence the temperature of the material will approach that of the drying air. It may be assumed that most of the heat picked up is consumed by evaporation, *i.e.* the rate of evaporation is proportional to the heat inflow. The heat inflow is proportional to the temperature difference between material and air. That is, if the heat inflow were constant, the rate of evaporation would be proportional to the above temperature difference. Lewis, McAdams, and Adams found that this was not so. The rate of evaporation fell off more rapidly as the temperature difference got less. The conclusion is that there is an increase in the thermal resistance of the material as the moisture content is reduced. This is in accordance with the results discussed in the section on Heat Transmission.

Fisher investigated the rate of drying of wool under constant conditions of temperature and humidity. He obtained curves relating to the percentage moisture content with time of drying. From the slopes, at various points of these curves, he obtained a series of instantaneous values of the rate of drying at a given moisture content. The values of rate of drying, when plotted against moisture content, gave curves of the same general slope as vapour pressure or "regain" curves. The curves were composed entirely of straight lines, there being three points of inflection in each curve. The curves show that, down to 31% moisture content, the rate of evaporation is constant, being the evaporation from free moisture surface. From 31% moisture content the rate of evaporation continues at a decreasing rate until 11% content is reached. Between 11 and 5% the rate of evaporation continues at a further decreasing rate. From 5% moisture content the rate decreases very slowly to zero, or rather to a moisture content of ½% or so.

Fisher[30] found that, for his samples of wool, down to 10% moisture content the rate of evaporation varied inversely as the thickness. Below this moisture content, proportionality did not exist.

How the rate of drying of wool fabrics varies with the temperature of the surroundings was studied by Barker,[33] by hanging a piece of wet fabric on one arm of a balance. The latter was enclosed in a vessel containing some sulphuric acid, and surrounded by a constant temperature bath. From readings of weight, taken at intervals, the rate of drying was obtained at the given temperature and humidity. His curves of evaporation *v.* time were similar to those of Fisher. It can be shown that, above 31% moisture content, the increased rate of drying, due to increased temperature, should be proportional to the increase of vapour pressure at the free water surface. Barker found from his experiments, that the rate was proportional to a vapour pressure corresponding to some temperature between that of the cloth and that of the surrounding air.

Barker's conclusions were that, of the factors—method of spinning, twist, variation in sett and picks, finish—the finish was the only one which influenced the rate of drying; and that a hard, clear-cut finish gave up, on an average, 57% more water in unit time than a soft-finished piece of material.

The rate of evaporation of water from cloth was studied by Faber and Hadden,[9] the results of whose measurements, corrected to the same temperature and humidity, are given in Table VII as the gms. of water evaporated from a square decimeter of cloth per hour; the samples are the same as in Table VI.

Table VII

Material	Water evaporated
Silk	1·827 gms. per hour
Wool	1·677 ,, ,,
Cotton	1·677 ,, ,,
Linen	1·802 ,, ,,
Birdseye	2·003 ,, ,,
Canton	1·597 ,, ,,

They drew the following conclusions—"The rate of evaporation is perhaps of less practical importance than the rate of wetting and the total capacity for water. A very rapid evaporation would cause undue chilling of the body surface, and a very slow rate would result in injury to the skin.

In Table VII the basis of comparison is the amount of water evaporated per equal surface area exposed. It is not stated whether, at the commencement of the measurements, the cloth was partially or completely wet, nor is it clear to what stage of drying the results refer. The rate of evaporation from partially wetted material is probably dependent on the structure of the fabric.

GENERAL SUMMARY OF WORK REVIEWED

In summarising the work reviewed, it is noted that most of the work is concerned with heat transmission. Very much less attention has been given to moisture and air permeability. The physiological aspect of the question has been studied extensively, and it is generally agreed that good clothing should permit of the following conditions being maintained—(1) clothing should be light, comfortable, and of pleasing appearance; (2) should not cling when wet, or feel cold; (3) should be capable of repeated laundering without damage or change of shape; (4) keep body temperature normal; (5) keep the skin dry and well ventilated with fresh, unsaturated air; (6) protect the skin from excessive radiation from the sun.

With regard to heat transmission work, there are, broadly speaking, two classes. In one class, the thermal conductivity of cloth was measured by methods which are usually applied to solid substances. In the other class an attempt has been made to reproduce the conditions of a garment worn on the body, as regards temperature and convection. In the former class, the temperature of, and the temperature gradient in, the cloth were frequently quite different from those experienced in service conditions.

The presence of moisture was generally found to increase the conductivity of the fabric, as also did any pressure applied. The question of thickness of material was not investigated very closely other than by the use of multiple layers. By further consideration of some results it was shown that the porosity of the fabric was of first importance in relation to insulation provided.

Recorded results vary considerably owing to variations in the experimental conditions. From the point of view of comparing different materials, much of the work is valueless owing to lack of specification of the materials used. It is concluded that when dealing with fabrics, the best method is to consider the amount of heat transmitted by the actual fabric, and not conductivity, which is the heat transmitted by a layer 1 cm. thick, and the porosity of the fabric should be given.

Very little work has been done on air permeability of fabrics. The most important is that of Sale and Hedrick, who, however, did not relate their results with the other physical properties of the fabrics.

The results obtained for moisture permeability do not present much of interest. Hill found that there was no distinguishable difference between any of the fabrics he tested. The chief contribution to the study of absorbing and drying are those by Fisher and Barker. Barker concluded that the chief factor concerned in these processes was the "finish" of the cloth, this being of even more importance than the structure of weave.

November 1929

APPENDIX

In order to bring this review up to date it is now necessary to add a summary of papers which have appeared since it was first written. Some of these describe new work and others are in continuation of work already mentioned. It is noticeable, in most of the recent work, that a definite effort has been made to reproduce the conditions of a fabric worn on the body, and to find some relation between such hygienic qualities as heat transmission, etc., and the fabric properties weight, thickness, structure, etc. The majority of the papers dealt with in this appendix are concerned with heat transfer. In three, the energy required to maintain a clothed body at a given temperature is used as the basis of measurement. In three, the basis is the rate of cooling of warm bodies, which were usually at the temperature of the human body. In one case the radiant heat absorbed and transmitted by the fabric at room temperature is measured.

HEAT TRANSMISSION THROUGH FABRICS

Using the first of these bases of measurement, Hess, Floyd, and Baker[38] determined the "Protective Ratios" of a number of fabrics in still and moving air. They continued the experimental method previously described by two of them.[15] Thickness, weight, and porosity were recorded for each fabric. However, a sufficiently large number of tests was not made to enable any relationships to be found connecting these properties with "Protective Ratio". This ratio was found to increase as wind velocity increased, up to eight miles per hour.

By employing a similar type of method, protective ratios were determined for blanket materials by Weinrich,[39] and also by Freedman.[40]

Using the rate of cooling of a modified form of Hill's kata-thermometer, Burgess and Backmann[41] found a linear relation between heat loss and thickness. This only held in still air.

A method involving the rate of transfer of heat from a hot body, through the cloth, to a cool body was employed by Speakman and Chamberlain.[42] The hot surface was the base of a container filled with water maintained at 15° C. The cold surface (0° C.) was part of a Bunsen's ice calorimeter. These were taken to be the conditions of an undergarment worn next the skin, there being an outer covering and no connection. The thickness of the cloth could be measured in position. The moisture content of the cloth was determined by previous conditioning. They found, for wool, that specific conductivity increased with thickness at constant density; for wool, cotton and viscose, specific conductivity increased with density at constant thickness. The effect of weave structure was only manifest in so far as it altered the thickness or density. A formula, similar to that proposed by Sale and Hedrick, was derived, expressing insulation in terms of thickness and density only.

A method, similar to that used by Haven[14], was employed by Marsh.[43] The sample was placed as a sleeve between an inner cylinder at skin temperature, and a cool outer cylinder. The sleeve could either fit the cylinder tightly or be suspended on a frame at some distance from it; a definite air space was generally used. The Thermal Insulating Value of the sample was defined as—

$$1 - \frac{\text{Heat lost by covered cylinder}}{\text{Heat lost by uncovered cylinder}} \times 100 \text{ per cent.}$$

Thus the value was zero for the uncovered cylinder.

From tests made on a large number of fabrics, principally woollen materials, Marsh was able to conclude that, of the properties examined in relation to insulation, the chief determining factor was thickness. There was no definite relation between thermal insulation and weight per unit area. As regards apparent density, no definite relationships appeared, but the general observation was that higher insulating values were obtained for the less dense fabrics. The relative humidity of the atmosphere appeared to be unimportant.

Marsh's conclusion was that, as thickness was the chief determinant of insulating value, it should be possible to construct a fabric of desired insulating value by regulating its thickness and closeness of structure. The materials which had earned the name of being warmer than others were generally found to be those commonly used for making thick fabrics.

The results of the foregoing work were treated in more detail in a later publication.[44] Marsh was able to show, on theoretical grounds, that the effects observed were to be explained in the main by convective heat transfer. With increase of air permeability insulation decreased rapidly at first and then more slowly. In fabrics of the lower permeabilities, heat transfer from air to fabric took place more readily since the path of convection through the cloth was more devious than in the case of more open structural fabrics.

The absorption, transmission and reflection of radiant heat were studied by Gregory[45] in continuation of work already referred to.[10] The source of radiant heat was a 500 Watt tungsten bulb. The heat received through the cloth was measured by the increase in temperature of water circulating inside a receiver. When the cloth was in contact with the receiver, both heat absorbed and transmitted were measured; when the cloth was at a distance, the heat transmitted and half the heat absorbed were measured. The balance of the heat not received was taken as that reflected. The fabrics tested were of cotton, artificial silk or union. Gregory found that the heat directly reflected from a closely woven fabric may amount to 60% of the incident heat. In general, the absorption and reflection increased with weight of material. He concluded that no advantage, as regards tropical wear, would be gained by incorporating artificial silk with cotton as the former had a lower reflecting power. Certain ramie fabrics were found unsuitable as a protection against tropical heat, but on the other hand the fabrics tested were of an open structure.

Water Vapour Permeability

Gregory also did some further work[45] on moisture permeability of fabrics. His method was to measure the loss in weight of a dish covered by the sample containing water with its surface maintained at body temperature (37·5° C.). The water vapour escaped into an air-conditioned room at 20·5° C. From experiments with a series of special fabrics in which only the interspaces were available for moisture transference it was inferred that permeability consisted largely of diffusion through the interspaces. Also permeability varied only very slightly with number and size of the interspaces. A further conclusion was that when the fabric was in contact with a moist surface and fanned by a breeze, the rate of moisture transfer is dependent on the structure of the fabric and a considerable part of the moisture transfer is by absorption and rediffusion.

Air Permeability

In the same publication Gregory deals with air permeability, the definition being the volume of air passed by a given area of sample in a given time, under given pressure difference. There was a very large variation through the fabrics tested, of the order 2,300 to 1. Permeability depended considerably on whether the fabric itself was completely at rest or not. It was considered doubtful whether the ventilation provided by a garment worn on the body has any relation to its permeability to air. Any movement of the cloth drives the air in and out through the usual vents.

The permeability of fabrics to air was also studied by Marsh,[46] whose method was the comparison of the rate of air flow through the fabric with the flow through a previously calibrated resistance, such as a capillary tube.

Air of controlled relative humidity was used. The permeability was defined as the volume of air, at 73° F., 760 mm. of mercury, and 70% R.H., passing through a square cm. of fabric under a pressure of 1 cm. of water. A very large variation in permeability was found for the range of cloths tested, which were of various knitted and woven structures. There was also a considerable variation from one part to another in the same fabric.

SUMMARY

As already pointed out, most of the workers cited above have used body temperature as the standard at which the insulating value was to be measured. Some have used skin temperature, which is lower, but some have used temperatures as low as 15° C. It is generally considered that convection and radiation and wind should be allowed full play if body conditions are to be realised. The thickness of the material is generally considered to be the chief operating factor where the densities of the material are fairly comparable. Otherwise, if the thicknesses are much the same, density is the chief operative. As regards moisture permeability, very small differences are experienced from fabric to fabric unless the "hole areas" are very different. In the case of air permeability, however, very large variations are found by two different experimenters; one of these points out that any movement in the sample has a quite important effect on the permeability. This is important, as such movement is an essential part of body conditions.

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14—THE PHYSICAL PROPERTIES OF FABRICS IN RELATION TO CLOTHING

PART II—WATER VAPOUR PERMEABILITY OF FABRICS

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INTRODUCTION

It has been laid down by physiologists that one essential condition for comfort is that the layer of air next the skin must be maintained in a dry condition. Under tropical conditions or after exercise in a moderate climate, the body loses surplus heat by the conversion of water into water vapour, and clothing must be capable of allowing its escape. For this reason the statement is frequently made that high permeability to water vapour is a necessary characteristic of a good clothing material. It is, however, evident that this water can be removed from the skin by other means, such as by convection currents in loose-fitting garments, or the clothing may absorb by contact. This question of loss of heat by evaporation must also be considered in relation to that of the heat-retaining properties of fabrics. Measurements have been recorded of the permeability of fabrics to water vapour, but always without sufficient definition of the structure of the materials compared. It was, therefore, considered necessary to carry out measurements on linen fabrics of known origin, and to determine the effect of variation of structure. This also has the advantage that other properties of these same fabrics, related to their value as underclothing, could also be determined. By this means it was hoped to be able to obtain more definite information than is at present available, about the relative importance of these different properties which it has been claimed, on rather insecure evidence, must be considered.

EXPERIMENTAL METHOD

The method adopted for measurement of the rate of transmission of water vapour through a fabric was the straightforward one of determining the loss in weight, with time, of water contained in a vessel, the top of which was covered by the fabric under examination. This method has been employed by several workers, but from accounts published prior to the commencement of this work, it appeared that no precautions had been taken to ensure constancy of the humidity of the air and of the air movement at the cloth surface. As it was considered essential that these factors should be controlled, a box was constructed of convenient size in which experiments could be carried out at constant temperature, humidity, and controlled small air movement. Arrangement was made in this box for the simultaneous testing of six dishes, five covered and one uncovered for control. The dishes were weighed without removing them from the box or disturbing the atmospheric conditions therein, by hanging them in turn on a calibrated spring within the box. Measurement of the extension of the spring was made by a cathetometer mounted outside the box and reading through the glass front of the latter.

The dishes used were of aluminium, of section as shown in Fig. 1. They were about 40 c.c. capacity and inside diameter 5·5 cms. Round the upper edge of each dish there was a flange having a rim 4 mm. in height. An ebonite washer of thickness 4 mm. and width equal to the width of the flange, was dropped into the flange. The fabric was fastened to the ring with rubber solution. The cloth was laid on without tension, any creases being smoothed out. Any space between the ebonite ring and the rim of the flange was filled in with paraffin wax. The rim of the flange had a thin brass strap riveted to it and was provided with a hook for suspension from the spring and holes for registering with two small pegs on the support.

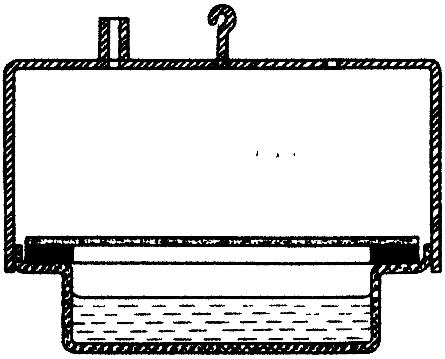


Fig. 1

It was noticed that distilled water did not wet the sides of the aluminium dish uniformly and a wavy line was obtained at the surface boundary. Use of a 0·5% solution of saponin instead of distilled water completely eliminated the fault and considerably improved the agreement between results obtained from six uncovered dishes tested at the same time as a check on the suitability of the arrangements. By experiment and calculation it was found that the vapour pressure of this solution was indistinguishable from that of pure water. With 20 c.c. of this solution in each dish, the surface was 1 cm. below the layer of fabric or the top surface of the ebonite ring. The diameter of the test area of cloth exposed was 5·5 cms.

The constant temperature enclosure was built of "celotex" composition and was 26 inches square in front and 12 inches from front to back. The front consisted of a double parallel glass window. In the sides of the box were two holes covered by vertically sliding doors. Around the holes, on the outside, were attached sleeves which fitted tightly around the wrists so that the hand could be inserted to make adjustments inside. The box was heated by two carbon lamps placed so as to overhang a dish of humidifying material. The temperature was regulated in the usual way to one degree Centigrade. By an arrangement of deflecting screens and gauzes, air was drawn by convection through the floor of the box, past the heaters down over the surface of the humidifying material, vertically through the central part of the box where the evaporating dishes were located, through a final gauze and thence through small holes in the roof. In addition to these means of obtaining steady small air movement, the dishes were arranged on six radial arms which rotated horizontally at a very low speed. Thus each dish occupied the same position in turn. This speed was so low that no indication of air movement was given by a vane anemometer or by a kata-thermometer.

In weighing the dishes, it was found that any hysteresis shown by the spring was counteracted by allowing suitable rest and equilibrium periods. The calibration factor of the spring was 3·375 gms. per cm., accurate to three significant places.

With the foregoing arrangements the accuracy of working was such that the mean deviation of readings from six similar dishes, in a typical case, was 0·0004 gm. per hour, the average rate of evaporation being 0·505 gm. per hour at the particular temperature and relative humidity.

The usual experimental procedure was to start an experiment one morning and stop it the following evening, a duration of about 30 hours. During this time four readings were taken of the weight of each dish, thus giving the rates of evaporation during three intervals. The average of these three was taken as the rate of evaporation under the circumstances.

The measurements were all carried out with the air in the box maintained at 30° C. and air movement as small as was consistent with the maintenance of uniform conditions. This condition was decided on, as the primary object was the investigation of the vapour permeabilities of fabric in relation to their use as underclothing. The average skin temperature is in the neighbourhood of 30° C. In the case of underclothing there is little or no gradient of temperature through the cloth owing to the insulation of the outer garments and in indoor conditions air movement over the skin or underclothing would be very slight. This is the condition intended to be reproduced by our experimental conditions. The heating of the test dish over a bath, transmission being from bath temperature 30° C. to air at room temperature, as has been done by some previous workers, only represents the condition of a single garment worn on the body.

EXPRESSION OF WATER VAPOUR PERMEABILITY

It is not sufficient to express permeability as the weight of water vapour which passes through a given cloth covering of a dish under the given conditions of temperature, humidity and air movement. During the course of an experiment, which may last for some 30 hours, these three conditions may vary slightly, particularly air movement. The precautions taken against such variations have already been described. The uncovered dish which was always included in an experiment with covered dishes gives a rate of evaporation which is representative of the conditions of experiment. Consequently, it might be expected that the ratio of the rate of evaporation E_f from a covered dish to that E_w from an uncovered dish would always be the same under a variety of conditions.

Table I gives the rates of evaporation from an open dish and a dish covered with a linen mesh fabric at a variety of humidities; together with values of ratio E_f/E_w. Figures are also included for a plain weave linen fabric. The temperature was 30° C. and, in all experiments, the radius of the open dish and of the test area in the case of covered dishes, was 2·75 cms. and the sample specimen of cloth used throughout the series of measurements.

Table I

Sample	Relative Humidity %	Rate of Evaporation Covered Dish E_f gms. per hr.	 Open Dish E_w gms. per hr.	E_f/E_w
Linen mesh	15·9	0·264	0·428	0·616
	37·6	0·214	0·373	0·574
	44·4	0·184	0·320	0·575
	50·1	0·184	0·293	0·628
	58·7	0·174	0·264	0·659
	75·2	0·108	0·178	0·606
	80·1	0·088	0·138	0·637
Average for linen mesh	—	—	—	0·613
Plain weave linen ...	16·5	0·250	0·393	0·636
	36·9	0·197	0·371	0·531
	51·9	0·169	0·287	0·590
	58·5	0·154	0·245	0·629
	75·5	0·097	0·173	0·560
	82·9	0·075	0·121	0·619
Average for plain linen	—	—	—	0·594

The difference in the average values of the ratio E_f/E_w for the mesh and plain fabrics is small, but it is greater than the experimental error, as shown in Table II, which

Table II

Average temperature of air in box	30·7° C.
Average relative humidity	24·7%
Value of E for open dish	0·417 gms./hr.

Dish No.		Rate of Evaporation E_f Covered Dish gms. per hour
1	...	0·247
2	...	0·243
3	...	0·231
4	...	0·225
5	...	0·236
Mean deviation	...	0·0068

gives the value of E_f obtained, in one experiment, for five dishes covered with a plain loomstate fabric. The constancy of the values from the different dishes is quite good, but the deviation is larger than in the case of a number of open dishes treated in one experiment, probably owing to individual differences in the five specimens of the same cloth.

It would therefore appear that the variations in ratio E_f/E_w in Table I, although small, are too large to attribute to experimental error. The variation shown is irregular and is probably due to some variation in air movement conditions in the different experiments; this would have a more marked effect on the open dish than on the covered ones, due to shielding by the cloth.

There is always a difference in the temperature of the water when covered and when uncovered in any one experiment, due to the different rates of evaporation. If this temperature effect was affecting the ratio E_f/E_w in Table I, there would be a gradual change throughout the series of humidities, but this is not the case. Actually the rates of evaporation shown, both for covered and uncovered dishes, are closely proportional to the nominal difference in relative humidity. We considered that the slight differences in temperature of water, from dish to dish, which are consequent on the rate of evaporation from any dish, do not affect the use of this method for comparing different fabrics, since similar effects on skin conditions would also be produced under actual wearing conditions.

Throughout this paper the ratio E_t/E_w is used to express water vapour permeability, since it gives a figure tending to eliminate the effects of chance variations in air movement conditions which at these low values cannot be exactly controlled or specified.

VAPOUR PERMEABILITY OF DIFFERENT FABRICS

Altogether, 42 different coverings have been used of which the structural characteristics are tabulated in Table III, together with values of the ratio E_t/E_w, which we can call the permeability of the cloth. In the majority of cases more than one determination was made at different humidities; as the ratio E_t/E_w has already been shown to be independent of humidity, the average results are given in this table. This table specifies the type of cloth, whether loomstate, finished as for sale, or laundered in a public laundry; the material in, and the size of the yarn and, in plain weaves, the ends per inch in the cloth. The table shows, also, the results of measurements of weight in ounces per square yard; thickness of cloth in mms. measured in a standard gauge all under the same compression; the apparent density of the fabric, and the percentage porosity or total air space in the cloth reckoned between the two facial planes of the cloth. These all provide means for definite quantitative comparison of the vapour permeability of the cloths with different characteristics which might possibly be expected to have some relation to their behaviour.

The apparent density of the cloth was measured directly,[1] and is the weight of the sample divided by the volume between the two facial planes. The latter is measured by waterproofing the fibre with oil and filling up all air spaces between the yarns with vaseline, and the volume measured by immersion in water in an Armstrong Volumeter. Then if—

W=weight of cloth sample.
d_c =apparent density of cloth.
d_o =absolute density of fibre in cloth.

$$\therefore \quad \text{volume of fibre in sample} = \frac{W}{d_o}$$

$$\text{volume of cloth} = \frac{W}{d_c}$$

and total per cent. porosity=per cent. air in fabric $= \frac{d_o - d_c}{d_o} \cdot 100$

The figures for porosity are given in Table III and enable the openness of structure of cloths made from different kinds of yarns and fibres to be compared directly. It is the only way in which fabrics made by different methods such as weaving or knitting can be compared in terms of some common factor.

The plain woven linen material used was not of a type which is made or used for underclothing, but it was the only material available in which the

Table III

Water Vapour Permeability and Structural Characteristics of Coverings

Air temperature 30° C.

Sample Reference No.	Description		Yarn Count	Weight per sq. yd. ozs.	Thickness mm.	Apparent Density of Cloth	Total Air Porosity %	Permeability (E_f/E_w)
	Structure	State						
	Plain Weave Ends per in.							
29 C	20·2 × 34·1	Loomstate	2¼ lb. Dry spun line flax yarn bleached ¾ white	4·33	0·405	0·33	78·2	0·574
30 C	24·7 × 33·8	,,		5·12	0·413	0·42	72·0	0·580
31 C	29·3 × 33·6	,,		5·35	0·410	0·44	70·4	0·575
33 C	42·1 × 33·7	,,		6·69	0·475	0·50	66·4	0·562
34 C	45·9 × 33·8	,,		7·03	0·498	0·52	65·6	0·588
35 C	32·8 × 21·7	,,	,,	4·58	0·428	0·37	75·6	0·580
36 C	33·3 × 25·6	,,	,,	5·13	0·426	0·39	73·7	0·582
37 C	33·5 × 30·1	,,	,,	5·49	0·404	0·42	71·8	0·57
39 C	33·8 × 44·4	,,	,,	6·84	0·416	0·54	64·3	0·564
40 C	33·6 × 46·8	,,	,,	7·06	0·425	0·55	63·5	0·567
29 CF	22·1 × 32·4	Finished	,,	4·56	0·227	0·46	69·3	0·553
30 CF	26·7 × 33·2	,,	,,	5·12	0·226	0·52	65·3	0·527
31 CF	30·9 × 33·0	,,	,,	5·43	0·239	0·53	64·6	0·532
33 CF	45·0 × 32·3	,,	,,	6·54	0·275	0·57	62·0	0·516
34 CF	49·5 × 31·9	,,	,,	6·81	0·275	0·64	57·3	0·535
35 CF	36·3 × 21·3	,,	,,	4·65	0·227	0·45	70	0·569
36 CF	35·9 × 24·8	,,	,,	5·21	0·234	0·54	64	0·564
37 CF	36·2 × 29·2	,,	,,	5·32	0·239	0·56	62·6	0·550
39 CF	37·3 × 41·7	,,	,,	6·86	0·272	0·64	57·3	0·551
40 CF	36·7 × 44·4	,,	,,	6·74	0·281	0·66	56	0·552
29 CL	23·3 × 32·8	Laundered	,,	4·40	0·402	0·28	81·0	0·616
30 CL	28·9 × 32·8	,,	,,	4·90	0·405	0·33	78·2	0·585
31 CL	34·0 × 32·8	,,	,,	5·13	0·411	0·40	73·5	0·594
33 CL	47·2 × 33·6	,,	,,	6·38	0·415	0·48	68·2	0·585
34 CL	49·8 × 33·7	,,	,,	6·61	0·421	0·50	66·8	0·587
35 CL	36·1 × 21·7	,,	,,	4·41	0·356	0·33	75·25	0·613
36 CL	37·9 × 25·3	,,	,,	5·05	0·376	0·37	75·2	0·597
37 CL	39·0 × 29·0	,,	,,	5·17	0·389	0·42	71·8	0·585
39 CL	40·8 × 41·8	,,	,,	6·71	0·455	0·47	68·5	0·584
40 CL	40·3 × 43·5	,,	,,	6·59	0·444	0·51	65·8	0·579
MESH FABRICS								
112 CL	Mesh	,,	80's Flax, ¾ white	5·97	0·54	0·295	80·4	0·614
113 CL	,,	,,	30's Single cotton (American)	5·69	0·67	0·174	88·4	0·6013
114 CL	,,	,,	Art. silk, 350 denier	6·58	0·432	0·257	83·25	0·620
115 CL	Cellular	,,	31's 2-Fold cotton	4·07	0·506	0·182	87·8	0·598
116 CL	,,	,,	21's 2-Fold cotton	5·83	0·66	0·202	86·5	0·6008
120 CL	Knitted	,,	124's 2-Fold wool	7·37	0·66	0·172	76·4	0·587
121 CL	,,	,,	62·5's 2-Fold wool	10·21	0·83	0·209	74·2	0·585
WIRE GAUZES	Meshes							
	10 × 10	—	Copper wire	51·4	1·045	1·665	80·2	0·636
	29 × 30	—	,,	38·5	0·678	1·91	71·3	0·59
	40 × 40	—	Brass wire	27·6	0·413	0·265	66·4	0·588
	58 × 60	—	Copper wire	39·4	0·487	2·729	67·9	0·583
	86 × 90	—	,,	25·7	0·315	2·766	66·25	0·578

Note—In calculating the absolute porosity of the mesh fabrics, the densities of the fibres were taken as follows—

Linen	1·5 gms. per c.c.
Cotton	1·5 ,,
Artificial silk	1·53 ,,
Wool	1·32 ,,

In the case of the wire gauzes, the densities were found by experiment as follows—

10 mesh copper	8·45 gms. per c.c.
30 mesh copper	8·07 ,,
40 mesh brass	6·72 ,,
60 mesh copper	8·49 ,,
90 mesh copper	8·21 ,,

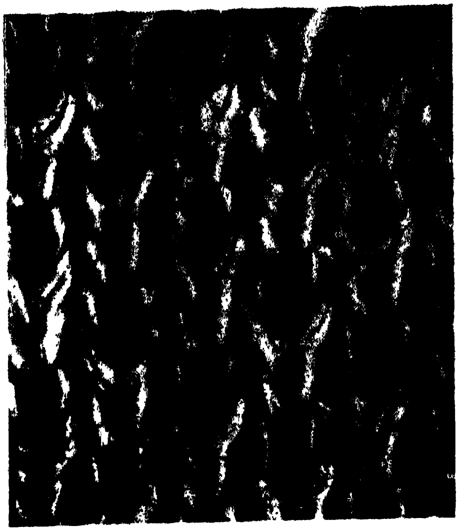
The apparent density of the gauzes was calculated from measurement of area, thickness and weight.

cloth was made from the same yarn with varying closeness of weave. In one set of samples the number of ends per inch warp way was progressively increased; in the second set of samples the weave was varied similarly in the weft, and was used as a duplicate set to check the first. It will be noted that as the closeness of weave increases, the weight per square yard and apparent density of cloth increase, whilst the total per cent. porosity decreases; and variation of thickness depends on how the structure is varied.

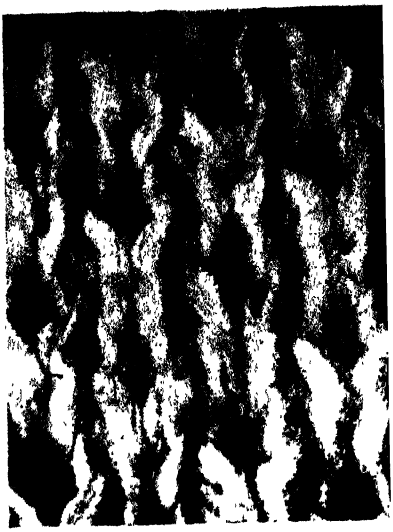
These ten samples were each used in the loomstate condition, after finishing, and after twice washing in a public laundry. During the finishing process a shrinkage in width and an extension in length take place, as shown by the ends per inch; the weight per square yard is only slightly affected, but owing to beetling and calendering, the fabrics are greatly reduced in thickness and consequently increased in apparent density and reduced in total porosity. During laundering there is a further shrinkage in width but only slight changes in length, as shown by the number of ends per inch; there is a slight loss of weight in each case, but the thickness increases considerably to approximately its loomstate value and consequently the apparent density decreases and the total porosity increases to a figure generally slightly higher than that in the loomstate condition. In the loomstate fabric part of the air space between the fibres in the warp yarns is occupied by size; during finishing and laundering this starch is removed and so accounts for the higher porosity of the laundered fabric, in spite of the yarns in the cloth being closer together owing to shrinkage. Actually it appears from the results that the chief difference between the loomstate and laundered cloths is that, in the latter the yarns are more porous or less compact, and that the spaces between the yarns are about the same.

These samples therefore provide coverings showing various markedly different characteristics, although all are made from the same yarn. In each of the six sets of five samples, there is a variation in porosity, together with a smaller variation in thickness. Between the loomstate, the finished and the laundered cloth there is a variation in porosity, together with a large variation in thickness. The loomstate and laundered provide a comparison, with cloths of approximately equal thickness, and equal interspace porosity, of a variation in yarn porosity. The values of $^{E_l}/_{E_w}$ for the five samples of any one set were obtained in one experiment at the same temperature, humidity and air movement.

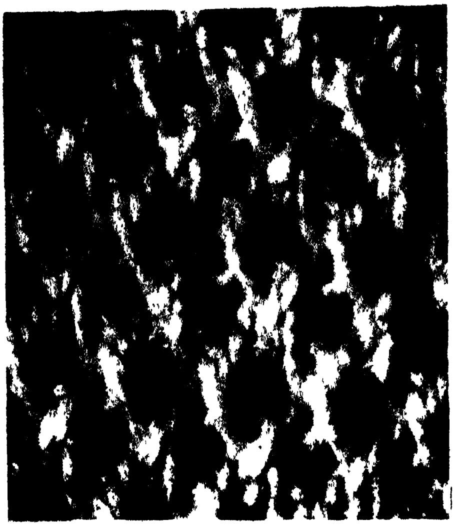
The samples 112–121CL were used for comparison of fabric made in somewhat similar structures, from yarns made from different fibres. The three mesh fabrics were identical in structure, being made on the same machine from linen bleached ¾ white, bleached cotton and artificial silk. The cellular samples were in two weights, light and heavy, and were knitted from two-ply bleached cotton yarn into structures of different textures. The wool samples were of similar construction, light- and heavy-weight in a ribbed, knitted structure. These wool samples are commercial articles of very high quality, and were selected as being as nearly equal in weight to the other samples as it was possible to get. All these samples are representative of commercial fabrics which are on the market and advertised as being essentially suitable for underclothing wear. The structure of these fabrics is illustrated in Plate I, in which the magnification is ten. The results of the measurements on the permeability to water vapour are set out in Table III.



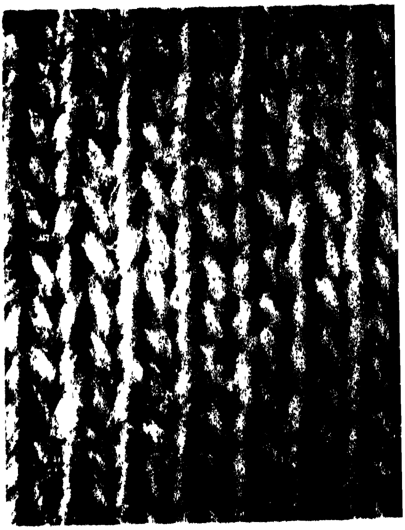
Linen Mesh (× 10)



Cotton Mesh (× 10)



Cellular Cotton (× 10)



Knitted Wool (× 10)

PLATE I

The remaining samples were ordinary wire gauzes with different sizes of mesh, and were included because preliminary results indicated that they might be of interest. They provide a further set in which the total porosity is similar to that of the fabrics used, but now it is all interspace porosity.

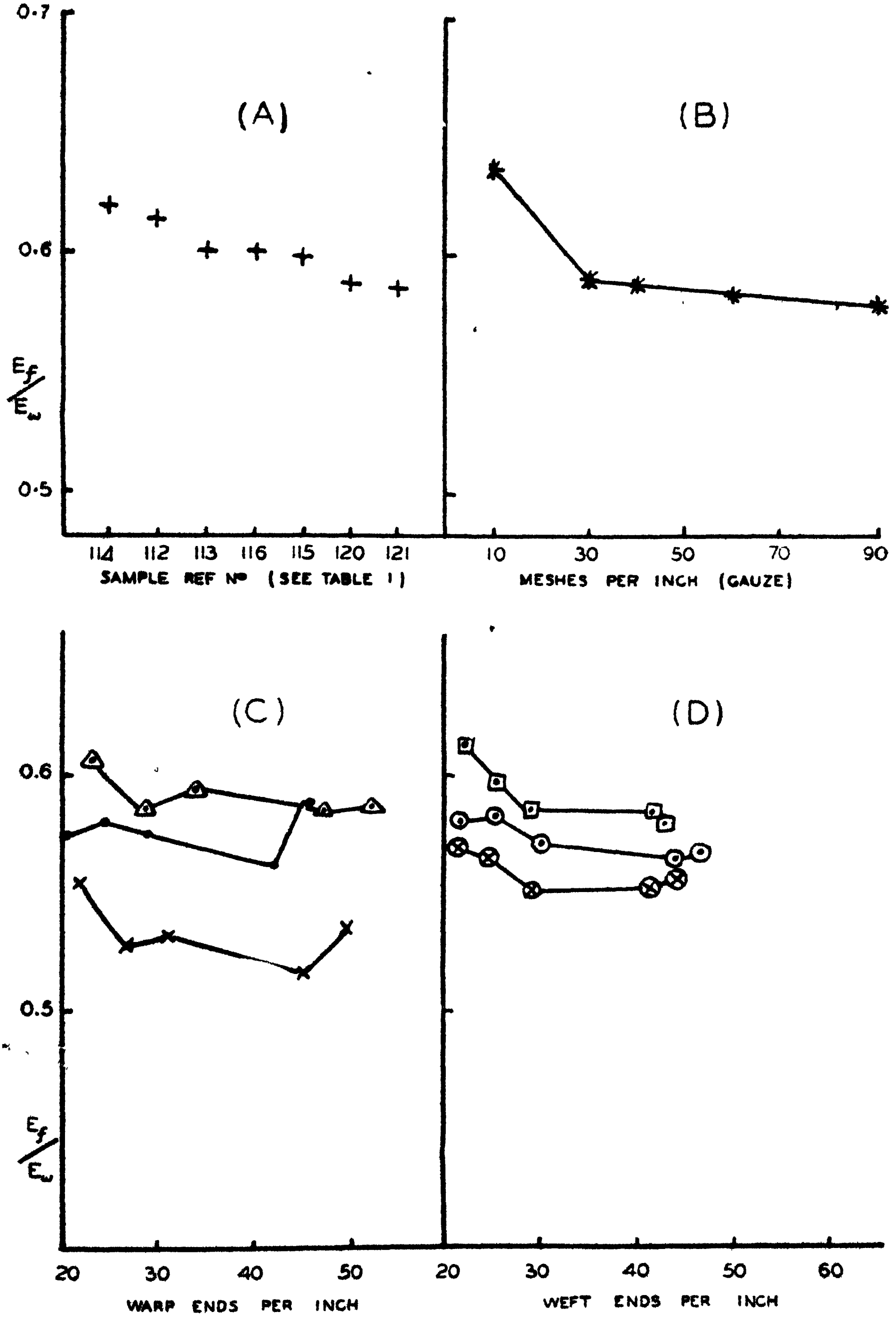


FIG. 2

EFFECT OF CLOSENESS OF WEAVE

The results for the permeabilities of the fabrics in Table III are shown graphically in Fig. 2, in which the ratio $^{E_f}/_{E_w}$ is plotted against the number of ends per inch, as this expresses the weave variation. For the sake of convenience the corresponding curves for loomstate, finished and laundered fabrics are shown in the same diagrams. In this and the following graphs the symbols used are as follows—

Loomstate, with warp variation ...	•
„ with weft variation ...	⊙
Finished, with warp variation ...	×
„ with weft variation ...	⊗
Laundered, with warp variation ...	△
„ with weft variation ...	⊡
Mesh fabrics	+
Wire gauzes	✱

It is clear from these curves, that whether the fabric be in loomstate, smooth finished or laundered and finished, and whether the weave is altered in closeness warp way or weft way, the permeability to water vapour suffers only a relatively small change with the very great variation made in the closeness of the weave. In all except the laundered samples with the increasing weft the average permeability shows a slight decrease followed at the end by a slight increase. The extent of this increase is generally small, and so it is difficult to say whether it is a real effect or merely an experimental and sampling error. The consistency with which the effect is shown is against the latter view. Brown and Escombe[2] noted an effect which is possibly analogous; they found, on obstructing the mouth of a tube through which diffusion was taking place, by a septum having a circular aperture in it, "that, after the aperture had been reduced beyond a certain point, the amount of vapour passing unit area in a given time showed a marked increase, which could not be accounted for by the difference in gradient of the partial pressures on the two sides".

In order to test the behaviour of a similar variation in coverings of a simpler type than cloth, a series of wire gauzes was tested, ranging from 10–90 mesh. The results for the permeability are given in Table III and shown in Fig. 2 (*b*) plotted against the meshes per inch. The curve shows a pronounced drop between 10 and 30 meshes per inch, followed by a further slow decrease. It is, therefore, very similar to the curves from the fabric samples, and indicates that in this type of structure, the permeability does not alter greatly until a certain openness is exceeded. The 10 mesh gauze would be much more open in structure than the most open fabric used.

EFFECT OF CLOTH TREATMENT

In making comparisons between the same cloths in the loomstate, finished and laundered conditions, the greatest change in the ends per inch of the same fabrics in the different conditions tested is never greater than four threads per inch, in either the warp or weft direction. Hence from the previous remarks, it is clear that in fabrics containing more than 30 ends per inch both ways, this amount of variation would have a negligible influence on the comparison of one curve with another. In both the examples given, the permeability of the laundered fabric is higher than that of the loomstate fabric, which in turn is higher than that of the finished fabric. See Fig. 2 (*c*) and (*d*).

EFFECT OF NATURE OF MATERIAL

The results for the permeability of the mesh fabrics are given in Table III and graphically in Fig. 2 (*a*). The table also includes the results for a sample of 60 mesh wire gauze which was tested in the same experiment with the mesh fabrics.

In this section we may regard the mesh fabrics as alternative materials—the fabric structures are not the same, but they are of the same type, loosely knitted materials expressly made and used for the same purpose. The order of decreasing permeability of these particular samples is artificial silk, linen mesh, cotton mesh, cellular cotton (heavy), cellular cotton (light), wool (light), and wool (heavy). The two weights of cellular cotton are of equal permeability as are the two weights of wool. The magnitude of extreme differences is of the same order as between the extremes of the plain weaves.

CORRELATION OF WATER VAPOUR PERMEABILITY AND STRUCTURE

Although the water vapour permeability shows very much smaller changes with very pronounced changes in structure than might have been expected, yet it is important to determine, if possible, what particular characteristics of the fabric can be correlated with the permeability.

The ratio $^{E_f}/_{E_w}$ is plotted against thickness in the lower part of Fig. 3, for the seven sets of fabrics tested. In any of the sets of plain woven fabrics, the variations of permeability and thickness are small, but if anything there appears to be an indication of a decrease in permeability with increased thickness. In the set of mesh fabrics there is a wider range of thicknesses, and the decrease of permeability with increasing thickness is shown more definitely. It is, however, clear that permeability is not solely dependent on thickness, because it will be seen that the points for the different sets of fabrics would lie on separate lines. The points tend to form groups for each set and the separation of some of the groups is more pronounced than the effect of thickness within any group. This appears to show that permeability is more dependent on some property, which is characteristic of each set of samples. This separation into groups is, in order of increasing permeability, plain weave finished, loomstate, laundered, and mesh fabrics. It has already been remarked that the loomstate and laundered samples have very similar structural characteristics, but in each cloth condition there is a well-marked difference in the nature of the cloth surface, although this cannot be expressed quantitatively. In the plain woven cloths the surface is smooth and flat when finished, but in the loomstate and laundered it is not flat but consists of a series of ridges corresponding to the yarns. The mesh fabrics have a still more marked departure from the smooth flat surface condition. It may be suggested, therefore, that the permeability of the cloth depends on its surface condition, which to some extent varies as the porosity of the cloth.

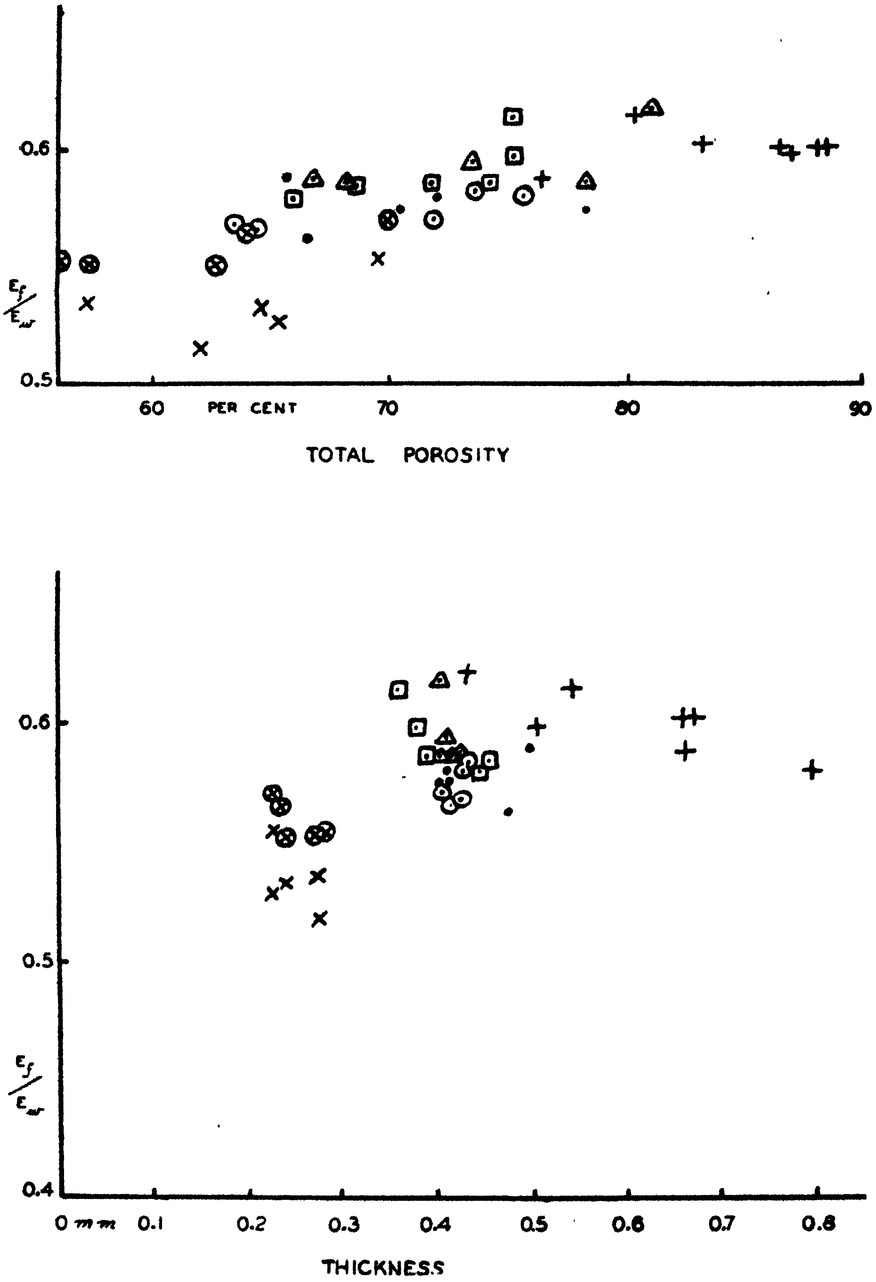

0.6
0.5
$\varepsilon_f / \varepsilon_{w}$
60
PER CENT
70
80
90
TOTAL POROSITY
0.6
0.5
0.4
$\varepsilon_f / \varepsilon_{w}$
0 mm
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
THICKNESS

FIG. 3

Taking the mesh fabrics as a group by themselves, we find that, although of higher porosity, the cotton materials have lower permeabilities than the artificial silk and the linen. By analogy with the woven fabrics one would expect the reverse to be the case. Obviously in this case there must be another factor operating which is of equal or even greater importance than porosity. It is significant that the order of increasing permeability, wool, cotton, linen, artificial silk is also the order of decreasing hairiness of surface. This is illustrated in Plate 1, which shows a selection of the structures used, magnified ten times. It is difficult to measure such a surface factor definitely. The nearest we can approach to it is by its possible inclusion in the apparent density figure. Even this, however, seems to fail where surface hairiness is concerned, as will be seen later. It is probable that diffusion of moisture takes place mainly through the interspaces in the mesh fabrics, where porosity is largely made up of "hole area". In this case, hairiness of surface would have a proportionally larger influence than in the case of the woven fabrics.

In the top part of Fig. 3, permeability is plotted against total porosity. Although the various sets retain their individuality to some extent, this is much less noticeable than in the case of thickness, and on the whole it might be concluded from these results that permeability is directly proportional to porosity.

In Fig. 4, permeability is plotted against fabric apparent density. As this property takes into account weight, thickness and porosity, a relationship might be expected between permeability and apparent density into which all the fabrics would fall, irrespective of weight, thickness or weave. It is noticed in Fig. 4 that, although the sets still retain their individuality, the members of the sets fall into lines which are close together and roughly parallel to the line of the graph. Low apparent density is accompanied by high permeability and *vice versa*. It is noteworthy that, of the mesh fabrics, only linen mesh and artificial silk lie on the line of proportionality. It may be concluded from this that there is some other property present in the two weights of wool, the two weights of cellular cotton and the cotton mesh, which is not included in the figure for apparent density. As already pointed out, these materials have a greater hairiness of surface than the linen or artificial silk. In the measurement of cloth apparent density surface hairs are smoothed down, and consequently the densities obtained for hairy fabrics are really too high. The permeabilities for these hairy mesh fabrics are lower than would be expected from the average line of Fig. 4. Therefore, if this can be attributed to hairiness of surface it must exert a considerable retarding influence on the escape of moisture vapour—as much in fact as would be occasioned by an appreciable tightening in weave.

WATER VAPOUR PERMEABILITY AND CLOTHING VALUE

By considering the behaviour of fabrics with extremes of cloth structure, it has been possible to show that variations in permeability do exist which can be approximately related to structure. The differences are, however, very small, only varying from 0·5 to 0·65 for the ratio $^{E_f}/_{E_w}$ in these extreme cases. Many of the closely-woven samples, having the lower permeabilities, would be entirely unsuited for use as underclothing material for various

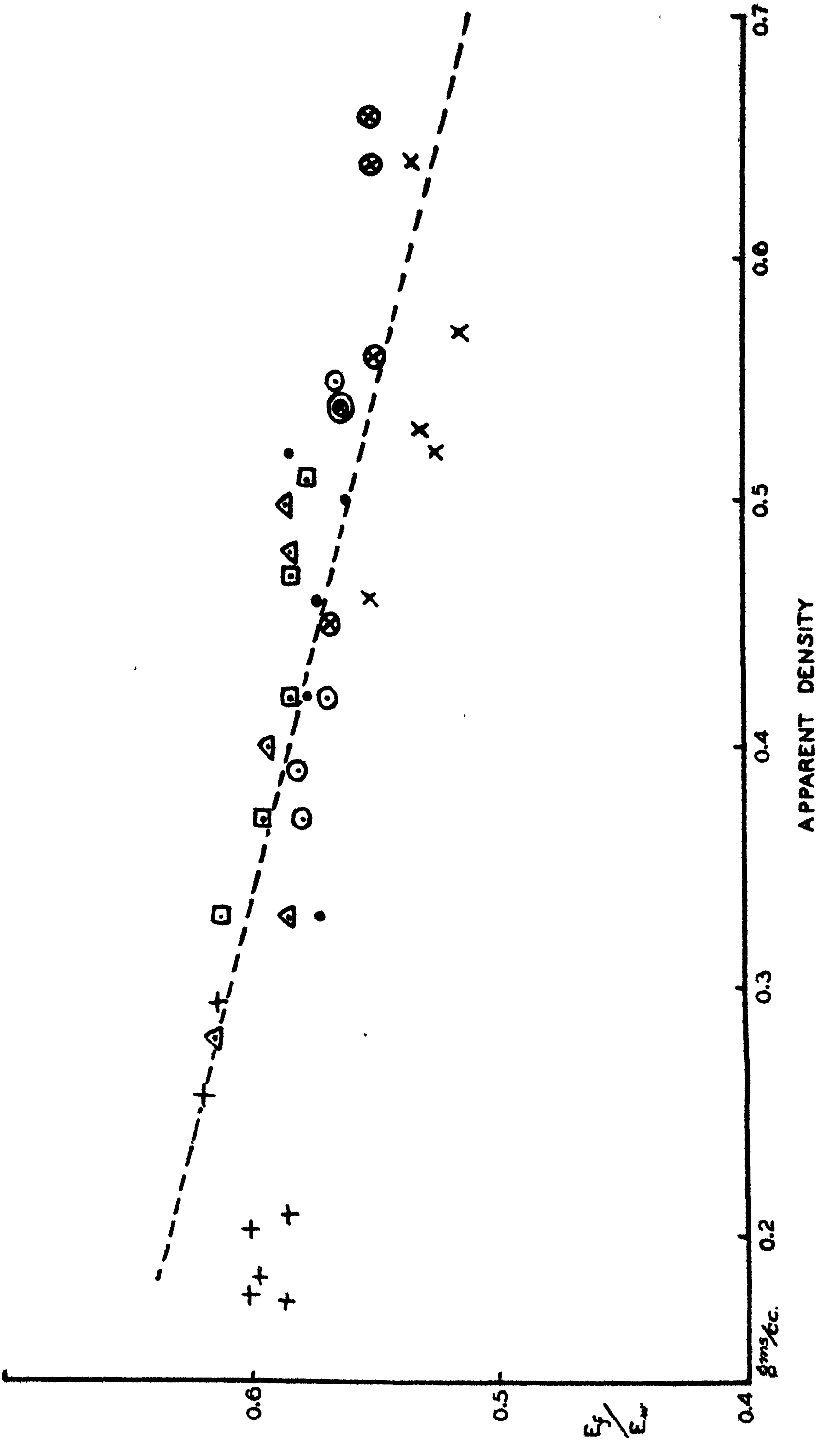


Fig 4

reasons such as stiffness, lack of heat-retaining power, etc. A truer estimate of the possible variation is got from the series of mesh fabrics, all of which are commercial underclothing materials. From these the variation in the ratio ${}^{E_f}/{}_{E_w}$ was 0·58 to 0·62. The conditions of experiment were such as might be supposed to exist in an undergarment in indoor or fairly still outdoor conditions. Since in the experiments loss of vapour could only take place through the cloth, the order of difference found must be a maximum when applied to actual wearing conditions, since there are usually some openings at the extremities, and so allowing air movements between the skin and the fabric, which are set up by convection and body movements. It therefore seems rather improbable that such a small order of variation in vapour permeability could be of any real importance as a criterion of the relative suitability of the material for use as underclothing. This is especially so considering the large variations in the structure of the fabrics tested.

We may conclude that transmission of body moisture through the fabric itself as vapour is not affected, to any appreciable extent, by the weave or material of the cloth. So, from this point of view, the physiological condition of the body is not influenced by the type of underclothing material worn. However, we may safely conclude that this channel for the removal of body vapour is of small importance in comparison with that supplied by the usual openings of the garment, and by absorption and drying. Thus, for body comfort, we must conclude that a loose-fitting undergarment should be worn and that its material, structure, and weight may be left to the taste of the wearer.

SUMMARY

The method employed for permeability measurement is by determining the loss in weight, from time to time, of a 0·5% solution of saponin contained in a suitable vessel, the top of which is covered with the fabric and sealed round the edges. Conditions of temperature, relative humidity and air movement are all controlled.

The figure taken as best expressing permeability is the ratio ${}^{E_f}/{}_{E_w}$ where E_f is the rate of evaporation, in gms. per hour, from a dish covered with the fabric, and E_w is that from an exactly similar dish which is uncovered, both rates being obtained in the same experiment. This method of expressing permeability gives a figure which is approximately independent of the surrounding air conditions.

Permeabilities are given for a series of linen fabrics of graduated openness of weave, each with several different surface states, and a number of fabrics of somewhat similar structure made from different textiles. Permeabilities are also given for a series of wire gauzes. Results show only a slight decrease of permeability with increasing closeness of weave. A similar effect is shown by the gauzes.

Woven materials, in the finished, loomstate and laundered states have permeabilities increasing in that order. The mesh fabrics give the greatest permeabilities.

The order of increasing permeability was found, in the mesh fabrics tested to be wool, cellular cotton, cotton mesh, linen mesh, artificial silk mesh.

Permeability is roughly proportional to porosity and inversely proportional to apparent density for the woven fabrics. In the mesh fabrics, the factors having the greatest influence on permeability would seem to be the hairiness of surface and the yarn interspaces.

The conclusion drawn is that since the vapour permeability shows only very small changes with considerable variation in the nature and structure of the underclothing material, it can have but very small influence upon moisture removal from the body, and therefore cannot be accepted as a criterion of the suitability or otherwise of such a material for its purpose.

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15—THE TESTING OF EYELETTED TAPES

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THE APPROVED METHOD OF TEST

In testing the strength of eyeletted tapes such as are used for aeroplane fuselage webbing, the procedure as defined by the British Standards Institution may be briefly described as follows.

Two pieces of the tape, each containing four eyelets, are clamped in the jaws of an approved testing machine and laced together with a length of Flax Kite Cord (No. 3 Twisted Cord. B.S. Specification 3.F.35) in the manner shown in Fig. 1. The rate of traverse of the extension jaw is required to be approximately 18 in./min., and the breaking load is divided by 2 to give the strength per eyelet. In the case of 1 in. eyeletted webbing as defined by British Engineering Standards Specification F.50 the strength per eyelet is required to be not less than 62 lb.

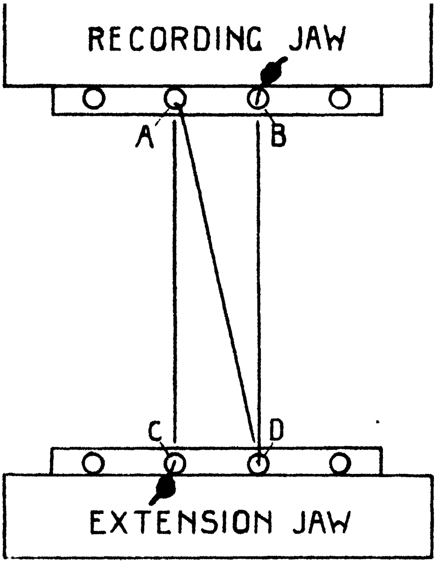

FIG. 1

In drawing up the specification this figure may have been decided upon in one of two ways. On the one hand it may have been found by the approved method of test to be the strength of a tape which was known to be strong enough, and therefore adopted as standard. On the other hand, it may have been arrived at solely out of consideration of the kind of loads to which the eyelets are likely to be subjected in actual use. The procedure implied by the second alternative is theoretically the more satisfactory, though seldom practicable, and does not seem likely to have been used in the present case; for if it had, a serious objection could be raised against the form of test. This objection is based on the fact that eyelets A and D (see Fig. 1) are subjected to appreciably greater loads than eyelets B and C, and it is invariably the defection of one of the first-mentioned pair that determines the result of the test. It follows, therefore, that dividing the total load by 2 does not do justice to the specimen. The devisor should be something less than 2, the exact figure being dependent on the distribution of the total load as between eyelets A and B, or between C and D. For reasons that will be made clear in what follows, a completely satisfactory figure representing this distribution is never likely to be determined.

Let us assume, therefore, that the procedure in drafting the specification was that given as the first of the alternatives mentioned above and that the specified strength is peculiar to the prescribed form of test.

The End-point of the Test

The strength of the specimen as a whole is not taken as the maximum load which it will sustain, but rather the load required to produce the first definite rent in the vicinity of one or other of the eyelets. The occurrence of such a rent momentarily permits of a small increase in extension without any increase in load, and when using a machine such as the Horizontal Goodbrand cloth tester, this is indicated by a more or less pronounced pause in the movement of the dial pointer, during which a snap reading may easily be made. At this stage the specimen as a whole is still intact and the load may be increased by a further 30 or 40% before a maximum is reached. Final breakdown usually occurs when the rent extends the full distance between two eyelets, whereupon that which carries the knot pulls out of the tape, and further stressing becomes impossible. Occasionally, however, one or other of the knotted eyelets pulls out prematurely, giving a relatively low maximum load.

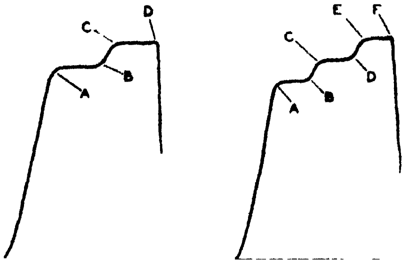

FIG. 2

A (*a*) First rent appears, say, at eyelet D.
(*b*) Pause ceases and specimen begins to take up further load.
(*c*) Initial rent commences to extend until at *d* it reaches eyelet C, whereupon the knot and eyelet are pulled out of the tape.

B (*a*) First rent appears at, say, eyelet D.
(*b*) Pause ceases and specimen begins to take up further load.
(*c*) Rent now appears at eyelet A.
(*d*) Second pause ceases and specimen again begins to take up further load.
(*e*) Initial rent, say, at eyelet D commences to extend until at *f* it reaches eyelet C whereupon knot and eyelet are pulled out of the tape.

Typical load extension records of a test are shown in Fig. 2. In Fig. 2a, the breakdown has been confined to one tape, while in Fig. 2b, the failures of both tapes have contributed to the complete record. For the identification of the eyelets in the subscription, refer to Fig. 1.

It may be here remarked that where the behaviour of the specimen has to be studied during the test, an autographic extension recorder is an indispensable accessory unless a second observer can be employed to make the necessary snap readings from the dial.

The Balance of Stress as between the Eyelets

The factors which determine the distribution of the stress as between the eyelets are as follows—

(*a*) The relative disposition of the four eyelets concerned;

(*b*) the friction between the cord and the eyelets;

(*c*) the freedom with which one or both of the jaws can swing to compensate for unequal stress distribution;

(*d*) the reaction of the knots at B and C to the applied loads.

In the case of fuselage webbing the eyelets are 1½ in. apart, and the distance between the jaws being 7 in., the distance between A and C and between B and D is approximately 6½ in. See Fig. 1. Hence ∠CAD=∠ADB= approximately 13° which is small.

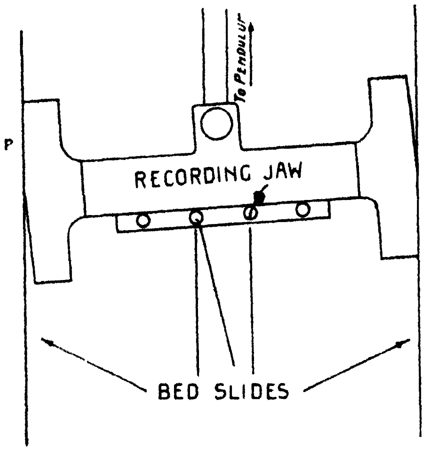

Fig. 3

From these dimensions, it can be shown that, at the instant loading commences, the forces acting on eyelets A and D are almost twice as great as those acting on B and C, and that a couple is set up tending to make the two jaws twist in an anti-clockwise direction. If both jaws were entirely free to do this, and if the friction between the cord and eyelets were negligible, the whole assembly would collapse laterally and the forces would finish by acting parallel to the tapes instead of normal to them.

In the Goodbrand machine, however, the extension jaw cannot rotate at all, while the other can do so only to a very limited extent. The result is that in practice the recording jaw swings very early during the test into the position shown in Fig. 3 and tends to jamb in the slides by lateral pressure. This is clearly one unsatisfactory feature in the test, for under these conditions the total force transmitted by the specimen is greater than that registered on the dial by an amount depending on the friction at the points P and Q.

The effect on the specimen of the swinging of the jaw is to relieve eyelets A and C at the expense of B and D, because owing to the friction between the cord and the eyelets, the tension in the length AC is less than that in AD, which in turn is less than that in BD. The increase in the angle CAD is also a contributing factor, but its effect is so small that it may be ignored.

On this account then it would be expected that the first rent would nearly always appear at eyelet D and not at A, the exceptions being accounted for by the fact that from time to time specimens will be found in which eyelet D is stronger than A by a margin sufficient to stand the greater burden. Whether this does in fact occur in practice, however, is very greatly dependent on the fourth factor mentioned above, namely, the reaction of the knots to the applied load.

The Effect of Various Methods of Lacing and Knotting

It is in this connection that the greatest criticism can be levelled at the present form of test; for, as will be shown, it is possible (while still adhering to the specified form of test) to obtain two results from the same fabric, one of 35% greater than the other, simply by varying the detail of the lacing and knotting.*

The crux of the matter lies in the tightness to which each knot is pulled before the test begins. This may be quite simply illustrated by reference to Fig. 1. If knot B is relatively slackly tied, while knot C is tight, the former gives out a short length of cord during the test, a fact which may easily be observed. Owing to the friction at D, which prevents any appreciable slippage of the cord through the eyelet, this has the effect of easing the tension in the length of cord BD, and throwing an increased proportion of the load on to eyelet A.

From this it follows that the first rent will appear at A in the majority of cases and that a decreased resistance from the specimen as a whole is to be expected. On the other hand, a counterbalancing effect is provided in the slewing of the jaw as already mentioned, though it is clear that whether these two opposing tendencies are exactly balanced must depend on the precise degree of slackness in the knot at B.

If now we take the case of knot C being slackly tied while knot B is tight, eyelet D becomes the bearer of the greater burden; and this, being already effected by the slewing of the jaw, will almost invariably be the first to break down at a very much reduced total load. Here, then, the two effects combine to produce a low recorded value instead of opposing one another to give what might be called a normal recorded value.

Against the foregoing it might be argued that it should be within the skill of any ordinary tester to tie both knots equally tight, in which case only the slewing of the jaw could be counted as a defect in the test. In practice, however, the two knots have to be tied under different conditions, such that it is extremely doubtful whether equality in tightness is achieved even where the tester is aware of its importance—which is likely to be rare.

The making of the first knot is a simple matter, because it can be done before the lacing commences; but the last knot presents a more difficult problem. Not only is there only one free end of cord left to handle, but there is also the close proximity of the jaw itself, which greatly hinders freedom of manipulation. If the specification with regard to the distance between the jaws has any meaning at all, it is clear that the knot must be tied fairly close to the eyelet, and anyone who has done the test must admit that to do so under the conditions prevailing requires considerable practice before a reasonable deftness is acquired. The important point to be considered is the way in which the last knot is tightened, and it is the author's contention that in this connection no amount of written instruction will ever lead to standardisation as between one observer and another, or even for one obsever on different occasions.

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* An ordinary single knot in the cord is too small and generally pulls through the eyelet. Hence a double knot has to be used.

Generally speaking, there are two ways of making the knot tight after tying. One is to grip the knot with the thumb and forefinger of one hand and with the other to pull as hard as possible on the short free end of cord. This is the most natural way of doing it and is probably the method actually employed in the majority of cases (for the sake of simplicity this will be referred to hereinafter as Method A). It should be noted, however, that a knot so tied is tight only to loads applied in the direction of the free end, and shows a very different reaction to loads applied in the other direction, as they are during the test. The other method (hereinafter called Method B) is to get hold of the cord between the eyelets and pull as hard as possible away from the knot. Of the two methods, B is undoubtedly the better, but even so, the satisfactory conduct of the test depends to too great an extent on the skill and experience of the tester, which may, or may not, enable him to tie both knots equally tight on every occasion.

With Method A it is a certainty that the last knot tied will be slacker than the first, to an extent which will no doubt vary from time to time, and from one observer to another. And whether the consequences result in augmentation or mitigation of the effect produced by the slewing of the jaw will depend entirely on which is the last knot to be tied. If it is that at B the two effects will tend to counteract one another, and a reasonably high test result may be expected. On the other hand if it is that at C a considerably increased stress will be put upon eyelet D and the test result will in consequence be a low one.

Experimental Evidence

The above argument has been developed only after making a large number of observations on the several aspects of the test, but may be illustrated here by the results of the culminating *ad hoc* experiment described below.

The material used was a roll of 1½ in. eyeletted fusilage webbing which differed from that required under the B.E.S.A. specification only in the matter of strength; and the following three series of tests were made—

Series I—Knots tied by Method A (above) with lacing order C, A, D, B (see Fig. 1).

Series II—As for Series A, but with the lacing order reversed, *i.e.* B, D, A, C.

Series II—Knots tied by Method B (above) with lacing order C, A, D, B.

In all cases the inevitable initial slackness in the cord was distributed by hand equally over the three sections, CA, AD, and DB.

Nine tests were made in each series on a Goodbrand 400 lb. horizontal cloth tester; and the samples were drawn and the tests made in rotary order, so that the results would be as comparable as possible. In each case note was made of the eyelet at which the first rent appeared; but where owing to the speed of the test, there was any doubt, the breaks were regarded as having taken place simultaneously at both.

The summarised results are given in Table I.

Table I

	Total Load at 1st Rent (lb.)	Number of Tests in which 1st Rent occurred at Eyelet		
		A	D	A and D simultaneously
Series I	83·1 ± 1·62	4	1	4
Series II	75·2 ± 1·41	1	8	–
Series III	87·0 ± 2·06	–	4	5

Considering Series II first, the results show clearly that the combined effects of the slewing of the jaw and of the slack knot at C have resulted in the overloading of eyelet D, it being the first to break down in eight out of nine tests.

In Series I eyelet D was the first to fail in only one test as compared with four for eyelet A, showing that the slack knot at B had rather more than compensated for the slewing of the jaw. The number of "simultaneous" breaks, however, show that the load was more evenly distributed than in Series I and in which connection the following figures are of interest.

Mean test result for 4 "simultaneous" breaks = 89·0 lb.
,, ,, ,, other breaks = 78·4 lb.

In Series III "simultaneous" breaks were recorded in five tests out of nine and the mean result of those was 89·8 lb. In the remaining four test (mean 83·5 lb.) eyelet D was the first to break down, thereby reflecting the influence of the slewing of the jaw.

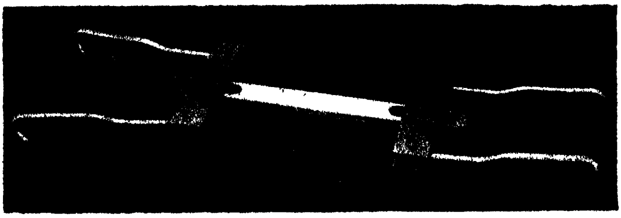

FIG. 4

The detailed technique employed in Series III was undoubtedly the best and that employed in Series II the worst, but recognising that all three series conformed to the specification of the test method, one cannot escape the conclusion that the whole procedure is too susceptible to variations in interpretation and personal judgment to be satisfactory as a standard test. With this in mind, an articulated system of metal links was devised, to replace the cord lacing by means of which the test would be made quicker, more accurate, and completely independent of the personal factor.

Testing with Metal Links

Fig. 4 shows the link system employed which was made in the College workshop. The four claws, a_1, a_2, a_3, and a_4, are attached to pins in the extremities of the cross-pieces b, b, so that they are free to swivel in the horizontal plane, as indicated by the position of claw a_2 in the photograph. Two pins, c, c, engaging with the slots in the centre link d, complete the articulated system. The slots in the cross-pieces are slightly wider than the centre link which passes through them so that a small amount of lateral play is permitted. Thus when the claws are hooked into the four eyelets under test, each eyelet is stressed in a direction at right angles to the selvedge of the tape, thereby obviating the slewing of the jaw, and the load is equally divided between them.

A comparison of the standard cord test, using the knotting method B, with the articulated link test gave results which are summarised in Table II. Forty-three tests were made in each case on the Goodbrand 400 lb. tester with a jaw speed of 18 in./min. and at a relative humidity of 34%. It will be observed that the link test gave a 27·4% higher breaking load than the cord test. This is explained by the fact that in the cord test, even under the most favourable conditions, as has already been implied, only two of the four eyelets are really effective in determining the result, the other two between them bearing little more than one-third of the total load.

Table II

	Standard Cord Test	Link Test
Mean breaking load lb.	79·3 ± 0·56	101·0 ± 0·67
Standard deviation	5·41	6·4
Coefficient of variability (S.D.%)	6·8%	6·3%

Even though every possible precaution was taken to minimise errors due to the personal factor in making the cord test, the insignificant difference between the two coefficients of variability was an unexpected feature of these results. In the link test the end-point is determined by the break down of any one of four equally stressed eyelets, whereas in the cord test, even under the most favourable conditions, only two eyelets are concerned. Hence greater significance might reasonably be expected from the better sampling provided by the former. That this was not so may be explained by reference to two circumstances attendant on the link tests here concerned. In the first place the autographic attachment was not used and in several cases considerable difficulty was experienced in making the snap readings of load at first rent, a difficulty which was absent in the cord tests. The pause in the movement of the dial pointer was found to be of much shorter duration, and in some cases the first such pause may have been overlooked altogether. Certainly in two cases the doubt as to when the first pause took place was so great that the results had to be ignored altogether. Secondly, it is possible that quite spurious results might have crept in owing to the very high velocity of the pendulum, since the "time to break" was found to be only about 1·5 seconds.

The test was therefore repeated on a new roll of tape using a reduced jaw speed of 4·9 inches per minute. This gave a "time to break" of approximately 7 seconds and eliminated the difficulty of making snap readings. The results of this test are given in Table III, from which it will be seen that the link test now gave significantly more uniform readings than did the cord test.

Table III

	Standard Cord Test	Link Test
Mean breaking load (40 lb.)	78·7	102·1
Standard deviation	6·79	6·07
Coefficient of variability (S.D.%)	8·63 ± 0·65	5·95 ± 0·45

The advantage of using the slower rate of loading was finally confirmed in a series of 100 tests using the links only, jaw speeds of 18 inches and 4·9 inches being used alternatively. The results summarised in Table IV show that the slower rate of loading, though giving a slightly lower mean breaking load, gave a considerably more significant mean.

Table IV

	Jaw Speed 18 in./min.	Jaw Speed 4·9 in./min.
Mean breaking load (lb.)	105·7 ± 0·88	96·9 ± 0·55
Standard deviation	9·13	5·66
Coefficient of variability (S.D.%) ...	8·65 ± 0·59	5·84 ± 0·39

CONCLUSIONS

The present standard method of test is unsatisfactory, not only because the test specimen itself is essentially an unstable system, but more particularly because the results obtainable depend so much on the skill and judgment of the operator.

A much more satisfactory test can be made by substituting a metal link system for the cord lacing, and by reducing the rate of loading to about a quarter of that at present required. The advantages of so doing may be summarised briefly as follows—

(i) The personal factor is eliminated so far as the preparation of the test specimen is concerned.
(ii) The mean of a given number of test results is more significant because of the better sampling provided.
(iii) The number of tests that can be made in a given time is almost doubled.

In connection with this last, it may be remarked that with the link system it only takes three or four seconds to connect the two pieces of tape together ready for the test to begin; whereas taking into account the time taken in cutting the kite-cord into the required lengths, the time taken to lace and knot a specimen by the present method is between 35 and 40 seconds; and that only after considerable practice.

A further matter which may or may not be of importance is the wear and tear on the operator's hands which is occasioned by the cord test. If the knotting is carried out in a proper manner blisters are not long in making their appearance.

With regard to the capital expenditure which would be involved by the adoption of the link test, this would be more than offset by the standing charges against the item of kite-cord in the case of the present test.

College of Technology
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CORRIGENDUM

"13—THE PHYSICAL PROPERTIES OF FABRICS IN RELATION TO CLOTHING

PART I—A REVIEW OF THE LITERATURE"

By C. P. Black and J. H. Matthew
(Linen Industry Research Association)

In this paper in the June issue a correction should be made on page T224, as follows—

Reference No. 33. *For* S. G. *read* A. F.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

16—THE PHYSICAL PROPERTIES OF FABRICS IN RELATION TO CLOTHING

PART III—HEAT INSULATION BY FABRICS USED AS BODY CLOTHING

By C. P. Black and J. A. Matthew
(Linen Industry Research Association)

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INTRODUCTION

Fabrics which are used as clothing for the human body have to fulfil many requirements, depending on the nature of the garment, the purpose, and the climatic and other conditions under which it is worn. The choice of any particular fabric may depend on its real suitability for the purpose in view, which may be comfort, ability to withstand wear, adornment value and so on. As regards the physiological aspect of the question it is generally agreed[1] that for body comfort the skin should be maintained in a dry condition, and body temperature should be kept constant, while occasional fluctuations of surface temperature cause a beneficial stimulation. In other words the heat flow from the body must be in equilibrium with the heat input derived from food. The chief channels of heat loss from the clothed body are radiation, convection, and the conversion of perspiration into water vapour and its diffusion through the clothing. Healthy clothing must facilitate heat flow in these three forms to the correct extent and no more. The present paper is only concerned with the properties of fabrics in so far as they may concern the comfort in wear by preserving the body temperature at a normal level. The discussion is further limited and simplified by considering mainly fabrics used as garments worn next the skin so that such indefinite questions as adornment and fashion can be disregarded to a large extent.

A great deal of work has been done by many investigators, usually dealing with one or other of the various aspects of the hygienic properties of fabrics. A review of this literature has been made by the authors[2] and also by Marsh.[3] In many cases the value of the results was doubtful owing to lack of sufficient description and specification of the materials used, whilst in some cases totally dissimilar fabrics, made from different materials, were compared.

In the experiments to be described, linen fabrics containing known variations in structure are largely used, and also some very similar fabrics made from different materials. The latter were not specially prepared but were selected from very good class commercial fabrics all sold for the same purpose. The experimental methods used were adopted on the grounds of simplicity of apparatus, the possibility of using the fabrics in a natural state as they would be in a garment, *e.g.* uncompressed, tight or loose fitting, as single or multiple covering. In the method used the losses of heat through the fabric by conduction, radiation and air penetration cannot be separated, as these effects are always present simultaneously in actual wear; this may, in fact, be an advantage and make it more possible to consider the relation of the results to actual wear.

EXPERIMENTAL METHOD

From the large number of methods available for investigating the thermal properties of fabrics, the kata-thermometer was chosen as providing the most suitable method for our purposes. The kata-thermometer was selected on account of its simplicity in use, the directness of the results obtained and the fact that its average operating temperature, 36·5° C. or approximately 98·4° F., is that of the human body. The design and theory of the instrument are given by its originator, Professor Leonard Hill, in various publications.[1] It consists of an alcohol thermometer with a cylindrical bulb about 4 cms. long and 2 cms. diameter, and a stem 20 cms. in length, having two graduations, one at 100° F. and one at 95° F. The stem terminates in a small reservoir which serves the double purpose of acting as a safety overflow reservoir in case of accidental overheating of the bulb, and of enabling the instrument to be heated well above the point at which observation has to be made. In order that its rate of cooling may be expressed directly in heat units the "water equivalent" of the instrument is determined by the makers and supplied in the form of a factor. When the factor is divided by the average time, in seconds, to cool through the graduated range, the result is the "cooling power" in millicalories per sq. cm. of the bulb per second.

By using the kata-thermometer unclad and clad with a cloth glove, the quantity of heat, in heat units, actually retained in the thermometer due to the presence of the cloth covering can be determined. The heat-retaining qualities of different fabrics can thus be compared by this means. Further, the instrument can also be used to investigate the different degrees of coldness which are felt, for example, on touching a piece of closely-woven, smooth-surfaced material and a piece of knitted material. For the measurement of this property the kata is first warmed up as usual, but is allowed to cool unclad until the alcohol reaches the top graduation (100° F.). At this instant the material, made up in cylindrical form, is applied to the bulb. The initial (maximum) rate of cooling produced is a measure of the "cold feel" of the cloth as this rate is determined by the surface conductivity of the cloth.

All the experiments have been carried out in a constant temperature enclosure, at 18·5° C., which was taken to represent an average summer outdoor and winter indoor temperature. In early tests, relative humidity of the air was also controlled, but this was found to have no measurable effect upon the thermal properties, and control was discarded later. The enclosure was a cube of 20 inches side, made of "celotex". It was heated by thermostatically-controlled carbon filament lamps. It could be cooled by flow of water in a special grid inside and was frequently run at less than room temperature by combined use of the cooling and heating elements. The photograph (Fig. 1) shows the method of mounting the kata-thermometer in the box. It was held vertically, in the centre, by spring clips.

The samples of cloth were prepared for test in various ways. The following proved the most satisfactory. The cloth was first made into a cylinder by wrapping it on a wooden former, marking off and sewing. Tabs were left at the top and bottom of the cylinder. By means of these tabs ebonite rings were fastened by shellac to the top and bottom. A disc of the same fabric was fastened to the bottom ring. To the top ring two wire supports were fixed, extending radially outwards. These could be hooked over a fork arrangement in the box and the cloth cylinder was thus held in the correct position for insertion of the kata-thermometer. These arrangements can be seen in Fig. 1. The cylinders were made in a series of sizes which gave annular spaces, between the thermometer and the cloth, of the following sizes—0·125, 0·25, 0·375, and 0·5 inch. All cylinders other than the close fit size were closed at the bottom with a thin ebonite disc, having a central cork stud ⅛ inch high on which the kata bulb rested when in position. The top of the cylinder was covered by a similar ebonite disc, the stem of the thermometer emerging through a central hole. In the case of close fit tests, the wire supports were found to be unnecessary as the cloth cylinder adhered by its own tension to the bulb of the kata. When used in the ordinary way, as already described, the cooling curve of the kata-thermometer when unclad and when clad, is a straight line.

An apparatus was used, by means of which the close-fitting cloth cylinder could be pulled on to the cooling bulb just as the alcohol meniscus was crossing the top graduation. At the same instant, an index finger was brought into position to follow the meniscus down the stem. These two operations were performed simultaneously by a single controlling movement. The index finger had connection with a pen moving on a horizontal recording drum. The drum was maintained in oscillation by a long pendulum of known period which could swing freely for about ten minutes. The arrangement of this recording apparatus is shown in Fig. 2 and has been described in detail in another paper.[4] With a little practice the meniscus could be followed very accurately by hand. The advantages of this method are that it provides its own time scale and is not so cumbersome as a photographic method of recording must be in the circumstances.

Expression for "Cold Feel"

By means of this apparatus, the cooling curve for the kata-thermometer can be obtained accurately over the graduated range. Under these circumstances, when a cold, closely-fitting covering is drawn on, the rate of cooling is accelerated for a time until the cloth becomes heated, and finally settles down again into a straight line. The cooling curve shows a distinct though small curvature at the top end of the graduated range. The initial rate of cooling at 100° F. was obtained by extrapolation from a curve constructed to show the instantaneous rate of cooling at several temperatures, obtained by drawing tangents to the original kata-thermometer cooling curve. This initial rate of cooling in degrees per second, was taken to be the "cold feel" of the samples tested. The figures recorded were always the average of the tests on three different specimens of the sample.

Expressions for Insulation

The insulating value of a fabric can be expressed as the percentage reduction in the cooling power of the unclad kata caused by the presence of the cloth glove. This figure allows for any slight variation in the temperature of the surroundings, as shown by the unclad reading. Actually, in the experiments detailed later, such variations were kept within plus or minus 1° C.

Another expression for insulation, perhaps more convenient in use, and the one adopted in this paper, is the ratio, t_c/t_u, of the time to cool over the range when clad (t_c), to the time to cool unclad (t_u). The advantage of this ratio as compared with the per cent. reduction in cooling power is that it avoids the negative values. In the case, for example, of a kata-thermometer clad with a wet cloth, when t_c may be less than t_u, and the per cent. reduction in cooling power would be negative, the insulation ratio is less than unity. It is equal to unity when the material is completely conducting, and infinitely great when insulation is perfect.

Scope of the Investigation

Of the physical conditions which might be expected to influence the insulation and cold feel of a fabric in its relation to the kata-thermometer, the following were investigated.

(1) The effect (on insulation) of the amount of air space between the cloth and the thermometer.

(2) The effect of air movement (fabric dry and wet; single layer, and with outer cover).

(3) The effect of the moisture content of the material.

These three effects are interpreted in terms of comfort to the person of a sedentary worker.

Of the textile properties of the material which exert their influence upon insulation and cold feel, the following were investigated—the nature of the material (linen, cotton, wool, silk) and closeness of weave.

EXPERIMENTAL RESULTS

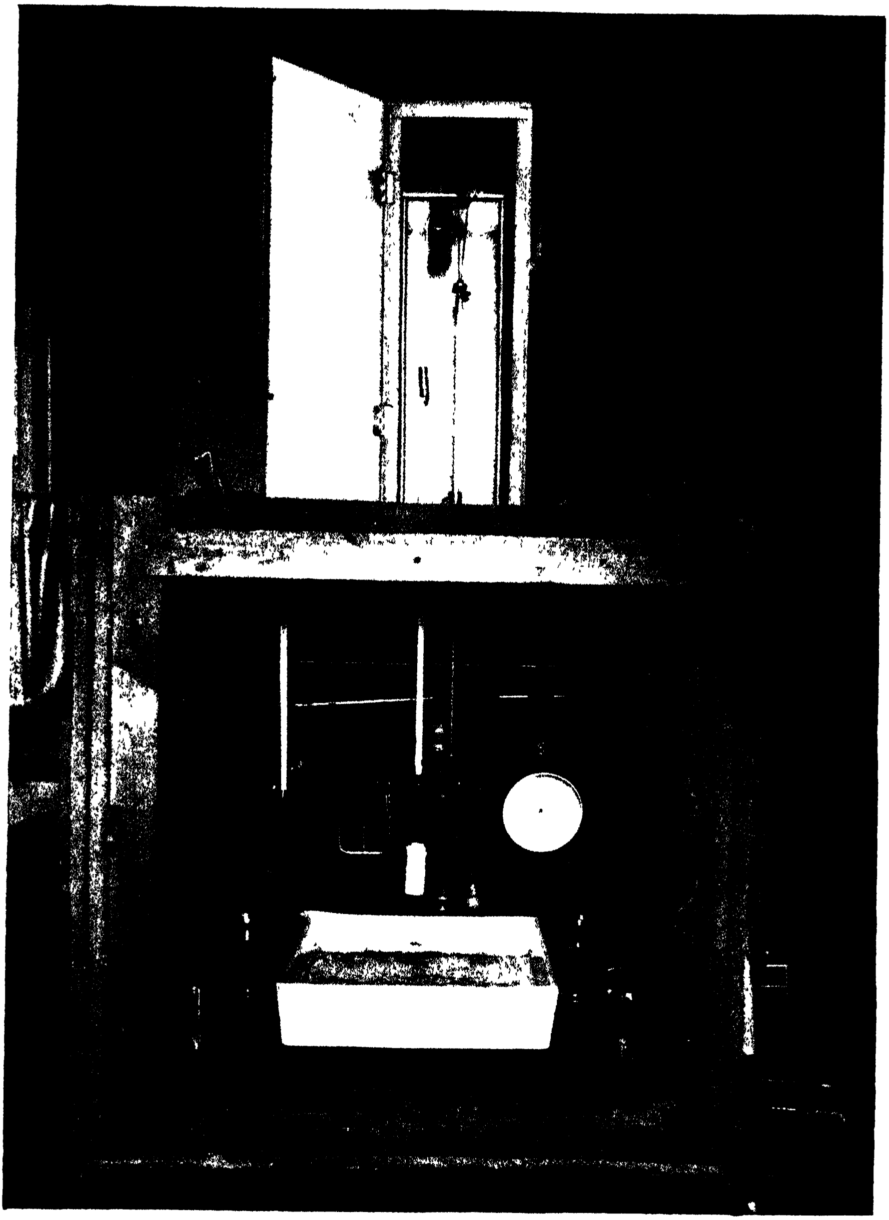
The Effect of Air Space

The results obtained for a number of different kinds of coverings are summarised in Table I and some typical cases are shown graphically in Fig. 3. In Table I, the figures t_u are given in seconds. Measurements for these were made by using a stop watch reading hundredths of a second. The variations in t_u are attributed to some slight difference in air movement conditions in the various experiments. The figures t_u given in brackets are values for the "wet" kata without covering, this being the equivalent "unclad kata" value in these particular cases. For the sake of clearness the curves for the two plain weave samples 35 CL and 40 CL are not included in Fig. 3. They are similar to the others and their insulation values lie in the same range.

For all the materials tested it was found that the insulation ratio, t_c/t_u, plotted against the annular space between the covering cylinder and the kata bulb, showed a maximum value at about 0·3 inch annular space. This effect is shown in Fig. 3A, with dry kata, for some air dry textile materials and also for sheet copper, $\frac{1}{64}$ inch thick, and for copper gauze 30 meshes per inch. No matter what the nature of the material, the maximum value of the insulation ratio always occurred at much the same value of annular space when the cylinders were closed top and bottom, and the surrounding air approximately stationary. .

The wire gauze gave a curve similar to those for the mesh fabrics, but with lower insulation values throughout. The copper sheet gave the same type of result, but with much greater difference between its extreme values than any of the other materials tested.

The annular space-insulation curve, Fig. 3B, was obtained for a specimen of air dry knitted wool and repeated with the same cylinders of wool closely surrounded by a layer of cellophane in each case. The close fit value for the wool alone was only a little lower than that for the combination, but the latter was higher when there was an annular space. The combination gave a curve with a flatter top. Similar results were obtained by similarly covering the wire gauze cylinders.



(By permission of the Journal of Scientific Instruments)

FIG. I

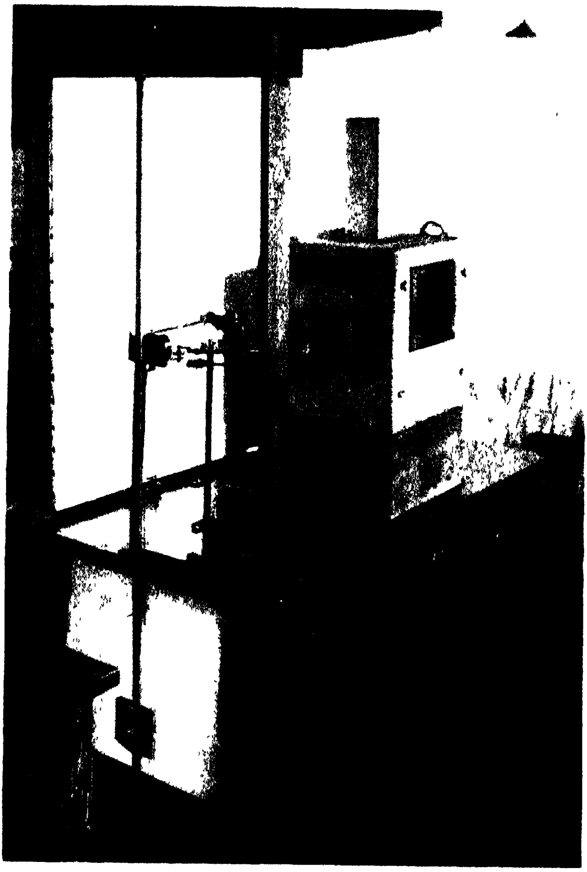


Fig. 2

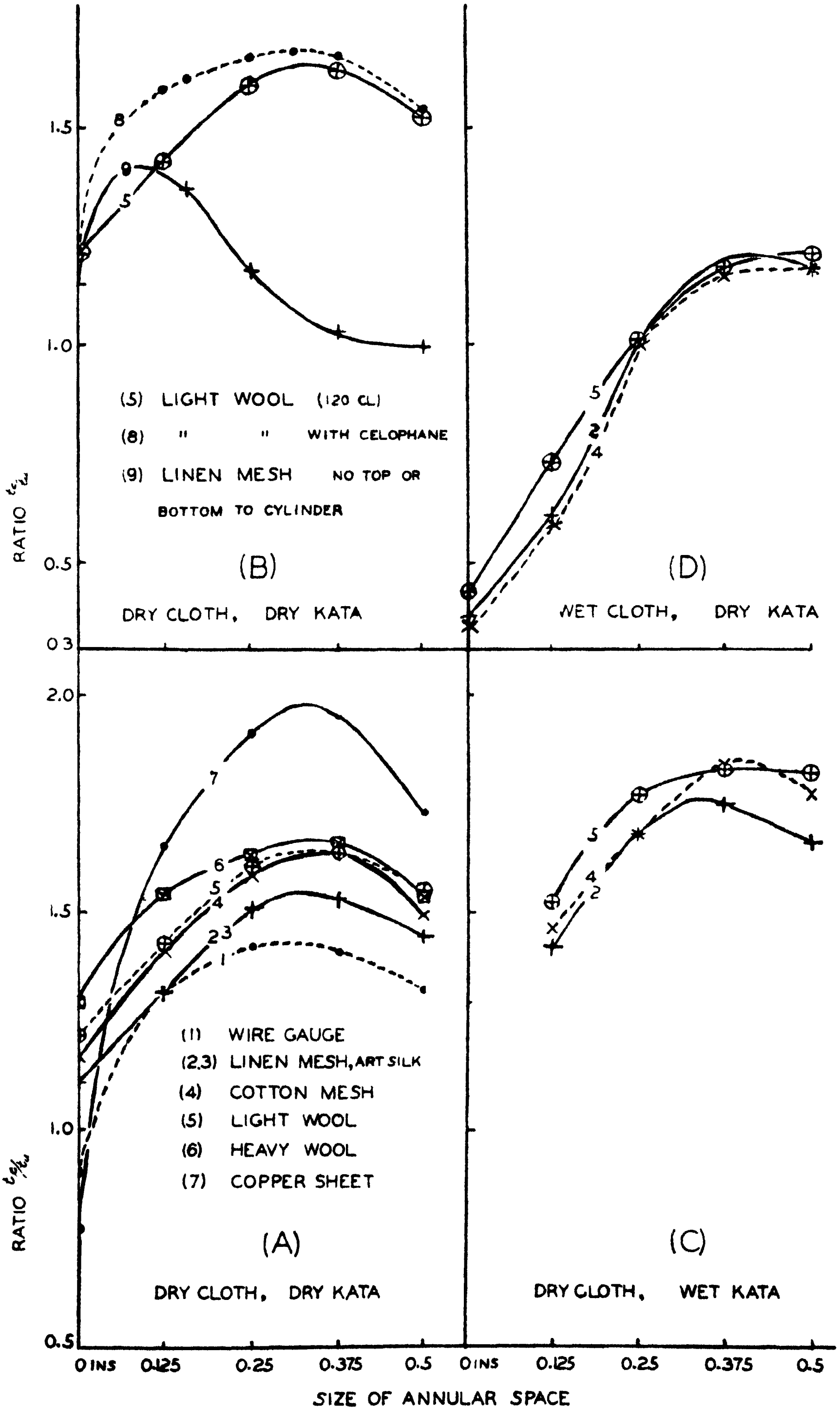

1.5
1.0
0.5
0 3
RATIO
(5) LIGHT WOOL (120 CL)
(8) " " WITH CELOPHANE
(9) LINEN MESH NO TOP OR BOTTOM TO CYLINDER
(B)
DRY CLOTH, DRY KATA
8
9
5
(D)
WET CLOTH, DRY KATA
5
2
4
2.0
1.5
1.0
0.5
RATIO
7
6
5
4
2 3
1
(1) WIRE GAUGE
(2.3) LINEN MESH, ART SILK
(4) COTTON MESH
(5) LIGHT WOOL
(6) HEAVY WOOL
(7) COPPER SHEET
(A)
DRY CLOTH, DRY KATA
5
4
2
(C)
DRY CLOTH, WET KATA
0 INS
0.125
0.25
0.375
0.5
0 INS
0.125
0.25
0.375
0.5
SIZE OF ANNULAR SPACE

FIG. 3

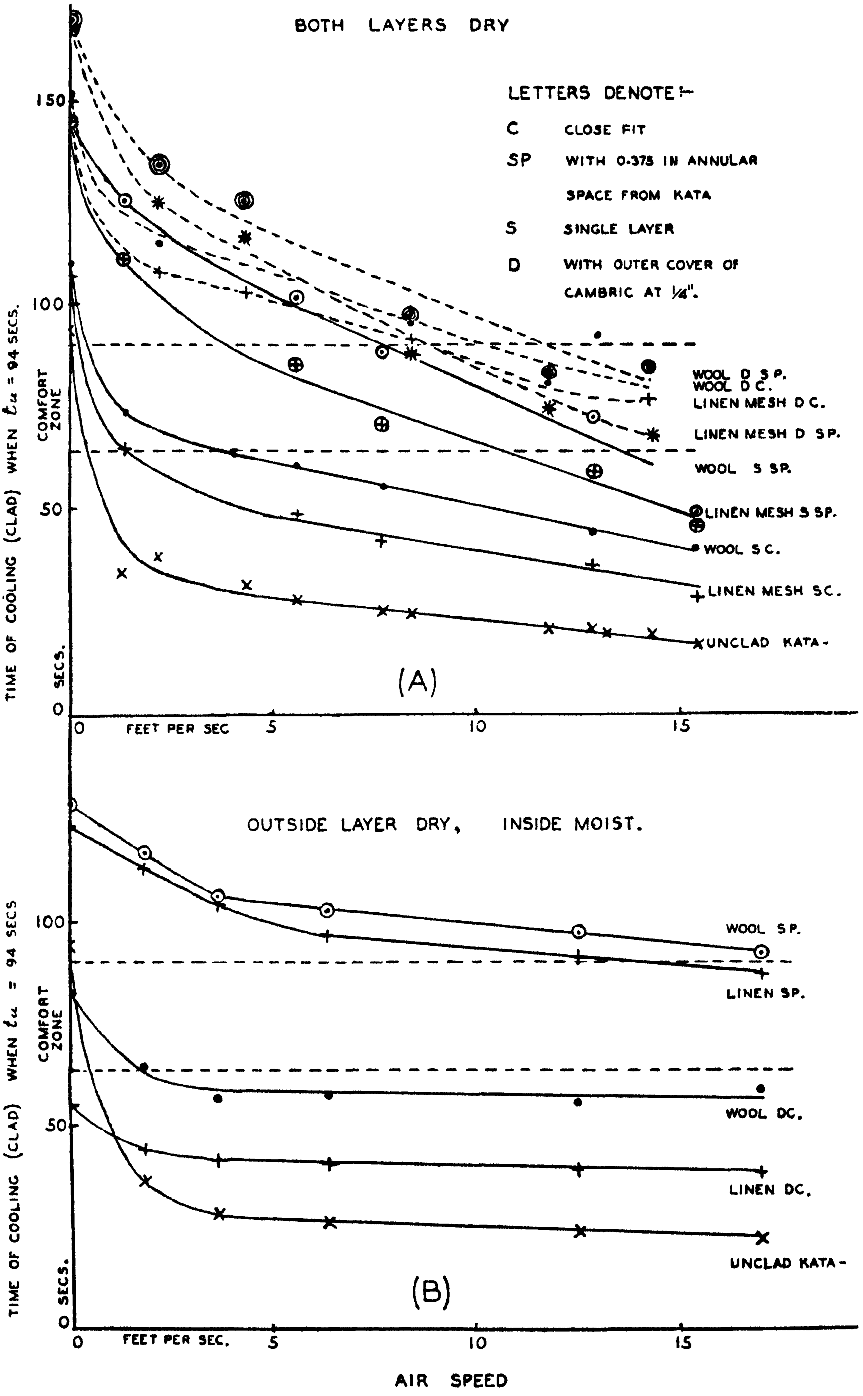

BOTH LAYERS DRY
LETTERS DENOTE:-
C CLOSE FIT
SP WITH 0·375 IN ANNULAR SPACE FROM KATA
S SINGLE LAYER
D WITH OUTER COVER OF CAMBRIC AT ¼".
WOOL D S P.
WOOL D C.
LINEN MESH D C.
LINEN MESH D S P.
WOOL S SP.
LINEN MESH S SP.
WOOL S C.
LINEN MESH SC.
UNCLAD KATA-
COMFORT ZONE
TIME OF COOLING (CLAD) WHEN tu = 94 SECS.
SECS.
150
100
50
0
0 FEET PER SEC 5 10 15
(A)
OUTSIDE LAYER DRY, INSIDE MOIST.
WOOL SP.
LINEN SP.
WOOL DC.
LINEN DC.
UNCLAD KATA-
COMFORT ZONE
TIME OF COOLING (CLAD) WHEN tu = 94 SECS
SECS.
100
50
0
0 FEET PER SEC. 5 10 15
(B)
AIR SPEED

FIG. 4

Table I

The Effect of Annular Space on the Insulation Ratio (t_c/t_u)

Air temperature = 18·5° C. for all experiments.

Sample	Condition	Relative Humidity %	t_u Secs.	Value of (t_c/t_u) at the Given Annular Space				
				0·0 in.	0·125 in.	0·25 in.	0·375 in	0·5 in.
Linen mesh (112 CL)	Dry cloth Dry kata	48	95	1·09	1·32	1·55	1·53	1·44
,, ,, ...	,, ,, ,, ,,	73	94·5	1·12	1·34	1·46	1·53	1·45
,, ,, ...	Wet ,, Dry ,,	45	96	0·38	0·61	1·09	1·19	1·17
,, ,, ...	Dry ,, Wet ,,	42	(33·1)	—	1·42	1·68	1·75	1·66
,, ,, ...	,, ,, Dry ,, (No top or bottom on cylinder)	38	93·6	1·14	1·36	1·17	1·03	0·995
Cotton mesh (113 CL)	Dry cloth Dry kata	45	93·4	1·16	1·41	1·58	1·63	1·49
,, ,, ...	Wet ,, ,, ,,	48·5	95·1	0·35	0·59	1·02	1·16	1·17
,, ,, ...	Dry ,, Wet ,,	46·5	(33·4)	—	1·46	1·68	1·84	1·77
Artificial silk mesh (114 CL) ...	,, ,, Dry ,,	48	94·2	1·11	1·31	1·50	1·52	1·44
Light knitted wool (120 CL) ...	,, ,, ,, ,,	47	91·0	1·21	1·42	1·63	1·68	1·58
,, ,, ,, ...	,, ,, ,, ,,	40	96·5	1·21	1·42	1·58	1·59	1·51
,, ,, ,, ...	Wet ,, ,, ,,	39·5	93·9	0·43	0·73	1·10	1·18	1·21
,, ,, ,, ...	Dry ,, Wet ,,	45·5	(33)	—	1·52	1·77	1·83	1·82
120 CL with Cellophane	,, ,, Dry ,,	40	94·4	1·21	1·59	1·66	1·66	1·53
Heavy knitted wool (121 CL) ...	,, ,, ,, ,,	47	93·3	1·29	1·54	1·63	1·65	1·54
Plain weave (35 CL)	,, ,, ,, ,,	49	94·3	1·17	1·51	1·57	1·57	1·48
,, ,, ...	,, ,, ,, ,,	44	94	1·08	1·38	1·55	1·52	1·45
Copper sheet	Dry kata	39	93	0·77	1·65	1·91	1·95	1·73
Copper gauze (30 mesh)	,, ,,	38	9·19	0·90	1·31	1·42	1·41	1·32

The curves in Fig. 3C refer to the same fabrics, but using the kata-thermometer bulb wet, and taking the ratio of the cooling times of this clad and unclad. The ratios are rather higher than with the dry kata, but generally the samples are in the same order, and the effect of increasing size of annulus is very similar.

In Fig. 3D some curves are given for cases where the kata bulb was dry and the coverings were wet. There is a slight change in the order of insulation at close fit, but also less actual difference. The effect of increasing annulus is again similar, showing a maximum insulation. A further point of considerable interest is that with these wet coverings, all the insulation values are very much reduced, and at the larger spaces all the wet covers tend to have the same value. Dry coverings preserve some individuality with varying annuli, whether this is due to the nature of material or to construction, but this is lost when the material is wet. It is interesting to note that the increase of insulation due to the use of an annular space between the cloth and the hot body was also encountered by Marsh.[8] The annular space he used was not increased far enough, however, to bring about the subsequent reduction in insulation. He also obtained similar results with sheets of metal.

The unclad kata-thermometer loses heat by radiation and convection. When clad with a close fitting cloth cylinder the kata-thermometer loses heat by conduction to and through the material, radiation through the interspaces in the fabric, and convection both in the interspaces and outside the cloth. When there is an annular space between the cloth cylinder and the kata bulb heat is lost in the same way as for close fit with the exception of conduction from the surface of the kata to the surface of the material. The explanation of the shape of the annular space-insulation curve probably lies in the convection rather than in the radiation effect. The covering cylinder, while receiving the same total radiation from the kata, is receiving less radiant heat per unit of area as its radius increases. Warming of the cylinder is therefore being reduced as far as radiation is concerned. Internal convection is restricted in the smaller annular spaces and warm air is allowed to pass through the material of the cylinder. As the annular space is increased in size there is more freedom for convection and air can be recirculated to the bulb while still warm. A relatively small diffusive interchange with the cooler outside air probably takes place at the same time. Any air diffusing inwards can be warmed by the cloth, which is still warm for small sizes of cylinder. So far, therefore, the effect of increasing the annulus is to increase the insulation of the kata. As the annular space is further increased a point is reached when the convective circulation is so great and the area of the cloth so large, and so much cooler (owing to decreased reception of radiation per unit area), that the air which is recirculated to the bulb has been chilled by contact with the cylinder, and by its reinforcement of cooler diffused air from outside. The limiting value of the insulation ratio is of course unity.

The results described appear to confirm these views. In the close fit samples, conductivity of the material predominates, as shown by the fact of the low values of t_c/t_u given by the copper gauze and sheet, and the small effect of adding an impermeable outer cover. When a definite annulus is present, convection around the kata bulb predominates and the samples show differences according to the way in which their air permeability affects this convection, e.g. the copper sheet gives the maximum insulation, and the insulation of a fabric is increased by the presence of an outer cover impermeable

Table II

Temperature 18·5° C. Average Relative Humidity 70%.

	Air Speed ft./sec.	Unclad Kata				Time of Cooling Clad / Time of Cooling Unclad $= \frac{t_c}{t_u}$				t_c Corrected for $t_u=94$ secs.			
		Still Air	In Wind	k_w/t_u	k_w for $t_u=94$	Close Fit		Ann Space=0·375 in.		Close Fit		Ann. Space=0·375 in.	
		$t_u$secs.	$k_w$secs.			112 CL	12 CL	112 CL	120 CL	112 CL	120 CL	112 CL	120 CL
Single layer	0·0	92·8	92·8	1·0	94·0	1·142	1·17	1·54	1·54	107·3	110·0	145·5	145·2
	1·31	92·8	33·6	0·362	34·1	0·643	0·783	1·18	1·34	60·5	73·6	111·2	125·6
	5·62	92·8	27·4	0·296	27·8	0·521	0·648	0·903	1·08	49·0	60·9	85·0	101·5
	7·70	92·8	24·8	0·267	25·1	0·453	0·585	0·75	0·94	42·6	55·0	70·5	88·5
	12·88	94·6	20·7	0·219	20·6	0·388	0·468	0·627	0·775	36·5	44·0	59·0	72·8
	15·45	95·45	17·0	0·180	16·8	0·298	0·425	0·485	0·619	28·0	40·0	45·6	58·2
With outer cover at ¼ in. space	0·0	94·5	94·5	1·0	94·0	1·59	2·01	1·79	1·81	150·0	—	169·0	170·0
	2·22	98·5	38·0	0·99	38·6	1·15	1·22	1·33	1·43	108·0	115·0	125·0	134·0
	4·34	98·3	33·3	0·339	31·8	1·098	1·2	1·23	1·33	103·0	113·0	116·0	125·3
	8·45	96·4	25·25	0·262	24·6	0·972	1·03	0·938	1·03	91·4	96·9	88·2	96·4
	11·8	95·2	21·0	0·221	20·8	0·834	0·855	0·788	0·879	78·4	80·4	74·5	82·5
	14·3	94·0	19·2	0·204	19·2	0·81	0·895	0·754	0·79	76·2	—	70·8	74·3
	0·0	97·8	97·8	1·0	94·0	—	—	—	—	—	152·5	—	—
	13·2	98·2	20·0	0·204	19·18	—	—	—	—	—	92·8	—	—
With outer cover dry and inside layer moist	0·0	98·0	98·0	1·0	94·0	0·593	0·875	1·31	1·37	55·7	82·2	123·2	128·8
	1·89	97·8	38·0	0·389	36·6	0·47	0·681	1·204	1·24	44·1	64·0	113·1	116·5
	3·65	96·4	29·4	0·305	28·7	0·445	0·602	1·13	1·11	41·8	56·6	105·8	104·0
	6·34	97·2	27·3	0·281	26·4	0·434	0·616	1·02	1·089	40·8	58·0	96·0	102·2
	12·5	98·0	25·2	0·257	24·15	0·42	0·587	0·963	1·03	39·45	55·2	90·5	96·5
	16·97	97·8	23·2	0·237	22·3	0·405	0·624	0·926	0·974	38·1	58·6	86·1	91·5

to air. A further reason for the increased insulation provided by the copper sheet and by closely woven, smooth surfaced linen under these conditions is the reflection of radiation. This was found by Gregory[6] to be as much as 60% for a closely woven fabric.

The effect of the annular space is very pronounced and variation in its magnitude can produce greater effects than, for example, changing the nature of the material in a fabric. The point is evidently of importance in connection with the fit of actual garments and also emphasises the need of strictly comparative conditions in laboratory tests.

The result of a test using the linen mesh cylinder without any top or bottom is shown in Fig. 3B. The maximum insulation was lower than previously (Fig. 3A) and occurred at a smaller annular space. In this case convection was freer and so the effect of circulation of the surrounding cold air around the bulb was shown at a smaller annular space.

The Effect of Air Movement

The effect of air movement upon the insulating value of linen mesh (112 CL) and the lighter knitted wool (120 CL) was investigated when the cylinders were close fitting to the kata and when there was an annular space of 0·375 inch in each case. Also the effect of an outer covering was tested in both cases and under both conditions. The outer covering consisted of a cylinder of a cambric material similar to a normal shirting fabric, which had been laundered. It was supported on the ebonite rings used in the construction of the inner cylinder, at a distance of $\frac{1}{4}$ inch from the latter, the space between the two cylinders being closed at top and bottom by the rings. The results of these experiments are summarised in Table II. The experiments were done in the constant temperature box as for still air. A fan supplied a draught of air at right angles to the axis of the cylinder and the air was recirculated in the box. The air speed was measured by a vane anemometer which could be substituted for the cloth specimen in the support. The wool and linen fabrics used in these tests do not compare identically, but these two represent fairly extreme types of normal fabrics both sold commercially for the same purpose, viz. underclothing. The observations made refer to these particular samples only and not to linen or wool in general.

For the test on any one sample, at a particular fitting, for a series of wind speeds, the time of cooling of the unclad kata in still air (t_u) was first taken. Then, at each wind speed, the time of cooling of the unclad kata (k_w) was taken, followed by the reading (t_c) for the particular cloth cylinder. Thus, in addition to the insulation ratio t_c/t_u, another ratio k_w/t_u was obtained for the series of wind speeds.

Instead of plotting the ratios t_c/t_u and k_w/t_u against air speed, each value of the ratio was multiplied by 94, thus giving the value of t_c or k_w which would have been obtained if the unclad, still air readings had always been 94 seconds. The reason for this is explained later. The values of t_c are plotted against air speed in Fig. 4A, in which is included the curve for k_w, the unclad kata. The latter shows the change in the insulating value of the air according to its degree of movement.

The insulation of any material in any condition is proportional to t_c. The curves, in Fig. 4A, for all samples and conditions are of much the same characteristic shape. Relatively speaking, wind exerts its greatest destructive effect on the insulating value of the material at speeds from still air up to about 2 ft. per sec., which corresponds to what is popularly known as a draught. At speeds above 2 ft. per sec. the rate of decay of insulating value is much less rapid. This rate is practically the same for the linen and wool samples, when both are closely fitting to the kata, and for both materials it is greater when there is an annular space between the cloth and the kata. The same order is observed for the samples with outer covers. Fig. 3 shows that in still air a certain amount of air space enhances the insulating value of the cloth. From Fig. 4 it would appear that, although at low wind speeds the air space inside the cloth has the same effect, at the greater air speed it is of no particular advantage. This is probably due to the greater air permeability of cloth in the higher air speeds. The curves in Fig. 4A are hyperbolic in shape and all tend to meet the unclad kata curve at the higher air speeds. At speeds of, say, over 25 ft. per sec., i.e. about 17 miles per hour, the insulating values of the materials tested, would apparently approximate to the same low value.

The advantage of converting results to t_e at a standard still air time of 94 secs. facilitates the introduction of Hill's "Comfort Zone" as a means of interpreting the experimental values in terms of personal comfort while wearing such coverings under these conditions. Hill gives the comfort zone for sedentary workers as lying between the cooling powers of 7 and 5. With our kata factor of 450, these values correspond to k_w (or t_e) equal to 64 and 90 respectively. Two horizontal lines are drawn at these values in Fig. 4A. Any point lying within the bounds of these two lines represents a comfortable condition, whether the kata, which represents the body, is unclad in still air or well covered up in moving air. For example, the close fitting, single layer wool is uncomfortably warm in still air. It becomes comfortable with the addition of a very light air movement and uncomfortably cool with a breeze of 4½ feet per sec. Under the same conditions the close fitting linen mesh, single layer, becomes uncomfortably cool at any wind over 1½ ft. per sec., and lies inside the comfort zone for a shorter range of air movement. Both of these linen and wool coverings, with annular space, do not enter the zone until higher winds are reached. Then they lie inside the zone for approximately equal ranges of wind, although wool retains the same degree of comfort in a higher wind than the linen. Further, comfort can still be maintained in a greater breeze with this single wollen covering than with this single linen covering. When an outer covering is used as well, comfort can be maintained in a much greater wind and also, in this case, the difference due to the material of the under covering is less.

It must be noted from Fig. 4A that the magnitude of the air movement has more effect on the cooling of the covered kata than has the nature of the material in the covering. The change in the insulating value of either the linen or the wool occasioned by the change from still air to the slight draught of 3 ft. per sec., is greater than the difference between the insulating values of the two kinds of covering at any given air condition. This would indicate that the air permeability of the fabric and the degree of movement in the surrounding air have a much greater influence on the comfort of the wearer than has the conductivity of the material.

It may be noted that the use of the standardised unclad still air kata reading of 94 secs. has caused the unclad kata curve in Fig. 4A to lie inside the comfort zone for only a very short range of negligible air movement

(0–½ ft./sec.). This is caused by our choice of temperature, 18·5° C., which is perhaps slightly low for the comfort of indoor sedentary workers. It may be presumed that an increase of still air temperature would merely move all the curves as a whole towards the higher insulation values. This would mean that the various cloths would give comfort, at the given temperature, over a much greater range of wind speeds, because those parts of the curves which have the smaller slopes would then be included in the zones. Thus it is evident that the comfort in wearing any particular covering depends to a very great extent on the prevailing extreme conditions.

The curve in Fig. 4A, for the unclad kata, at air speeds above 5 ft. per sec., approximates to a straight line for the range of air speed used. Over the whole range the curve is closely represented by the equation

$$H=3{\cdot}6+9{\cdot}56\sqrt{V}$$

where H is the cooling power of the kata, in millicalories, and V is the wind velocity in metres per sec. The equation provided with the katathermometer for its use as an anemometer, when converted for our conditions becomes

$$H=2{\cdot}52+8{\cdot}92\sqrt{V}$$

The small difference in the coefficient of $\sqrt{V}$ is probably due to the turbulence of the air flow in the present experiments.

The effect of wind was further examined on the same samples when the inner covering was moist and covered, as before, with the same dry, laundered cambric. This would simulate body conditions after strenuous exercise, when the undergarment has become damp by the absorption of perspiration. The degree of dampness was that acquired by the particular specimen, after contact overnight with a plug of saturated cotton wool. The plug was wrapped in a layer of filter paper and pushed into the cylinder, and the whole was kept over water in a desiccator overnight and also between experiments to prevent evaporation. It was found, by actual check weighings, that the moisture content of the inner cylinder remained approximately the same throughout each series of experiments.

The results of these experiments are also given in Table II and graphically in Fig. 4B. The curves are of the same characteristic shape as before, but the value for insulation at any wind velocity is, in general, less when the inside cylinder is wet. The insulation of the close fit samples is much more reduced by having the inner cylinder moist than that of the samples with an air space between the cloth and the kata. In the close fit condition, the linen has suffered a greater reduction in insulation than has the wool. A later experiment (see Figs. 7 and 8) shows that, using the same specimens, a great deal more moisture was absorbed by the linen than by the wool. This explains the foregoing effect. The curve for the effect of wind on the unclad kata in Fig. 4B agrees quite closely with the curve in Fig. 4A, so that the fabric curves in both cases are directly comparable. The "comfort zone" is also shown in Fig. 4B. It is observed that the slightest draught causes discomfort with wet, close fitting linen or wool cylinders worn with outer cover, but air movement up to 10 ft. per sec. is still comfortable with these close fitting coverings when dry. A peculiar effect is observed in the case of the samples with annular space and with outer cover. When the inner layer is either linen or wool, higher values of insulation are given when the inner

Table III

Values of "t_e" are given in secs., and refer to the condition "t_u" = 94 secs.
Moisture Excess, per cent., is represented by "M.E."

Close Fit						With Annular Space = 0·375 in.						
Linen (112 CL)		Cotton (113 CL)		Wool (120 CL)		Linen		Cotton		Wool		Condition of Experiment
Moisture Excess %	t_e (t_u=94)	M.E.	t_e	M.E.	t_e	M.E.	t_e	M E.	t_e	M.E.	t_e	
Air dry	111·2	Air dry	112·0	Air dry	124·0	Air dry	142·0	Air dry	153·2	Air dry	152·0	Still air single layer
222·0	35·4	337·5	36·0	317·5	30·4	232·0	113·0	316·5	117·0	318·5	116·8	
149·5	39·6	256·0	41·2	248·0	47·2	189·0	115·8	270·0	116·4	272·0	125·0	
5·03	102·0	65·0	47·1	83·1	57·5	81·8	121·1	162·0	123·7	164·0	123·2	
0·7	105·3	0·75	114·1	3·91	115·2	2·3	149·0	1·34	150·0	6·35	154·3	
−2·46	102·8	−3·36	104·8	−3·48	115·8	−1·8	145·2	−1·06	147·2	−2·31	153·6	
123·2	55·0	—	—	43·2	69·2	105·0	123	—	—	39·8	126·2	Still air with dry outer cover
96·0	54·7	—	—	22·18	77·4	106·0	123	—	—	27·42	126·5	
64·0	58·0	—	—	5·91	118·5	84·4	120	—	—	13·04	135·0	
42·2	58·3	—	—	−0·246	131·8	74·6	125	—	—	7·45	140·5	
1·03	130·0	—	—	−1·88	128·0	1·9	145	—	—	7·76	146·5	
110·0	40·8	—	—	44·6	52·2	137·8	96·1	—	—	38·0	103·5	At air speed of 6·05 ft./sec. with dry outer cover
78·2	40·6	—	—	20·7	63·6	108·5	97·6	—	—	23·75	104·5	
42·9	44·0	—	—	3·84	96·1	80·0	97·6	—	—	8·06	114·0	
23·7	58·1	—	—	−1·39	102·8	67·5	95·8	—	—	3·17	117·5	
−0·84	92·5	—	—	−7·55	98·1	0·086	111·8	—	—	1·14	121·2	
−2·34	93·7	—	—	−3·63	100·8	−1·3	110·0	—	—	1·832	121·8	

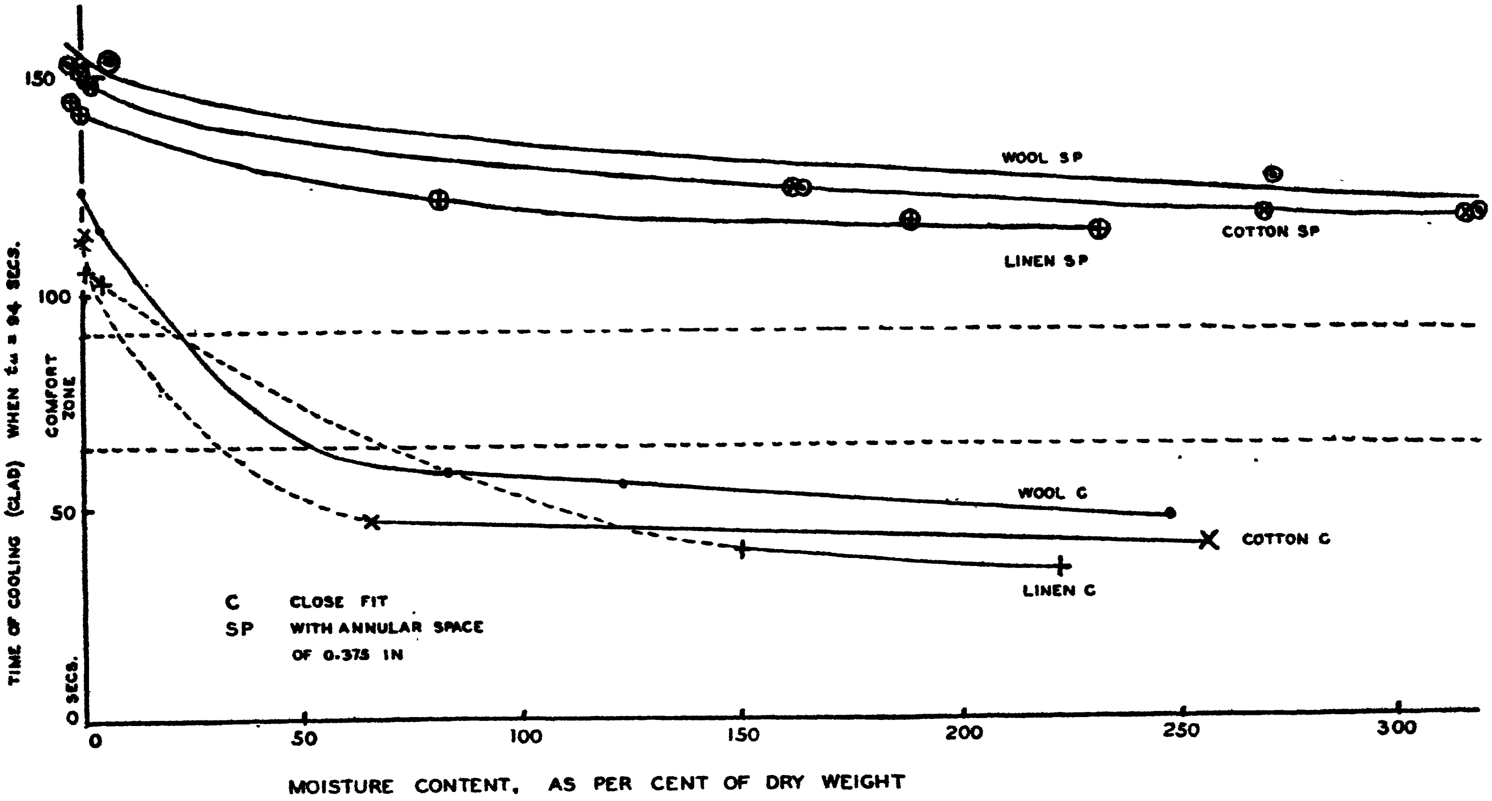

150
100
50
0 SECS.
TIME OF COOLING (CLAD) WHEN t_u = 94 SECS.
COMFORT ZONE
WOOL SP
COTTON SP
LINEN SP
WOOL C
COTTON C
LINEN C
C CLOSE FIT
SP WITH ANNULAR SPACE OF 0.375 IN
0
50
100
150
200
250
300
MOISTURE CONTENT, AS PER CENT OF DRY WEIGHT

FIG. 5

layer is moist than when dry, when the wind speed is over 10 ft. per sec. This is explained by the reduced permeability to air caused by the presence of the moisture. It will be remembered, referring to Fig. 3, and taking an extreme case that, while the close-fitting air-permeable wire gauze had a higher insulation than the impermeable copper sheet, yet when there was an air space of 0·375 inch, the impermeable material gave much the greater insulation. Thus, if an undergarment is wet with perspiration it will feel chilly, particularly in wind. The discomfort caused under such conditions would be considerably reduced if the undergarment were kept out of contact with the body. The nearest approach to this condition which can be made in practice is to wear loose fitting garments. Under such conditions the material of the garment has a more restricted influence on insulation and comfort.

Effect of Moisture Content of Fabric

The effect of moisture content of cloth upon its heat insulating power was tested in still air and in wind, when the cloth was close fitting to the kata and when there was an annular space of 0·375 in., both for single and double layers. As in previous experiments the second (outer) layer was composed of a cylinder of laundered cambric, and spaced at ¼ in. from the inner. Three materials were tested as single layers in still air, linen mesh (112 CL), cotton mesh (113 CL) and knitted wool (light) (120 CL). Two of these, linen and wool, were tested with outer cover both in still air and in wind of 6·05 ft. per sec. The results obtained are given in Table III in terms of moisture content (as per cent. of air dry weight) and the time of cooling, t_c seconds, for a value of t_u=94 secs. The coverings were allowed to absorb moisture to saturation from the soaking wet cotton wool plug by the method already described. The weight was recorded before each reading of the kata and between experiments the coverings were exposed to room conditions to dry, so obtaining a series of readings of decreasing moisture content. In each sample, the inner cylinder was accurately cut out, when air dry, and weighed. This air dry weight was the basis of the percentage excess moisture calculations. The negative values of moisture excess obtained in some cases are explained by the fact that, in those cases, the relative humidity of the air was a trifle higher during the air-dry weighing than during some of the experiments. The results from the single layers in still air series are shown in Fig. 5, and the others in Fig. 6, and the "comfort" zones are shown in each figure. Whether single or double, close fit or with annular space, in still air and in wind the insulation decreases from the air dry value. The effect of increasing moisture is most pronounced over the range 0–75 per cent. This decrease is much more marked when the cloth is a close fit than when there is a space. In still air the addition of the outer cover gives a slight increase in insulation at all moisture contents (see Fig. 6). The effect of wind is, in general, to lower the insulation of the material at all stages of moisture content. It is noticed in Figs. 5 and 6 that, under any one of the conditions, still air or wind, whether single or double layer, and particularly in the close fit condition, the effect of changing the moisture content only from dryness to 50%, is very much greater than that of changing the material from linen to wool or cotton at any particular moisture content. Obviously in comparing the relative comfort of different garments they should be compared at different moisture contents if they differ in absorbency. In practical wear there would usually be absorbency and drying going on simultaneously.

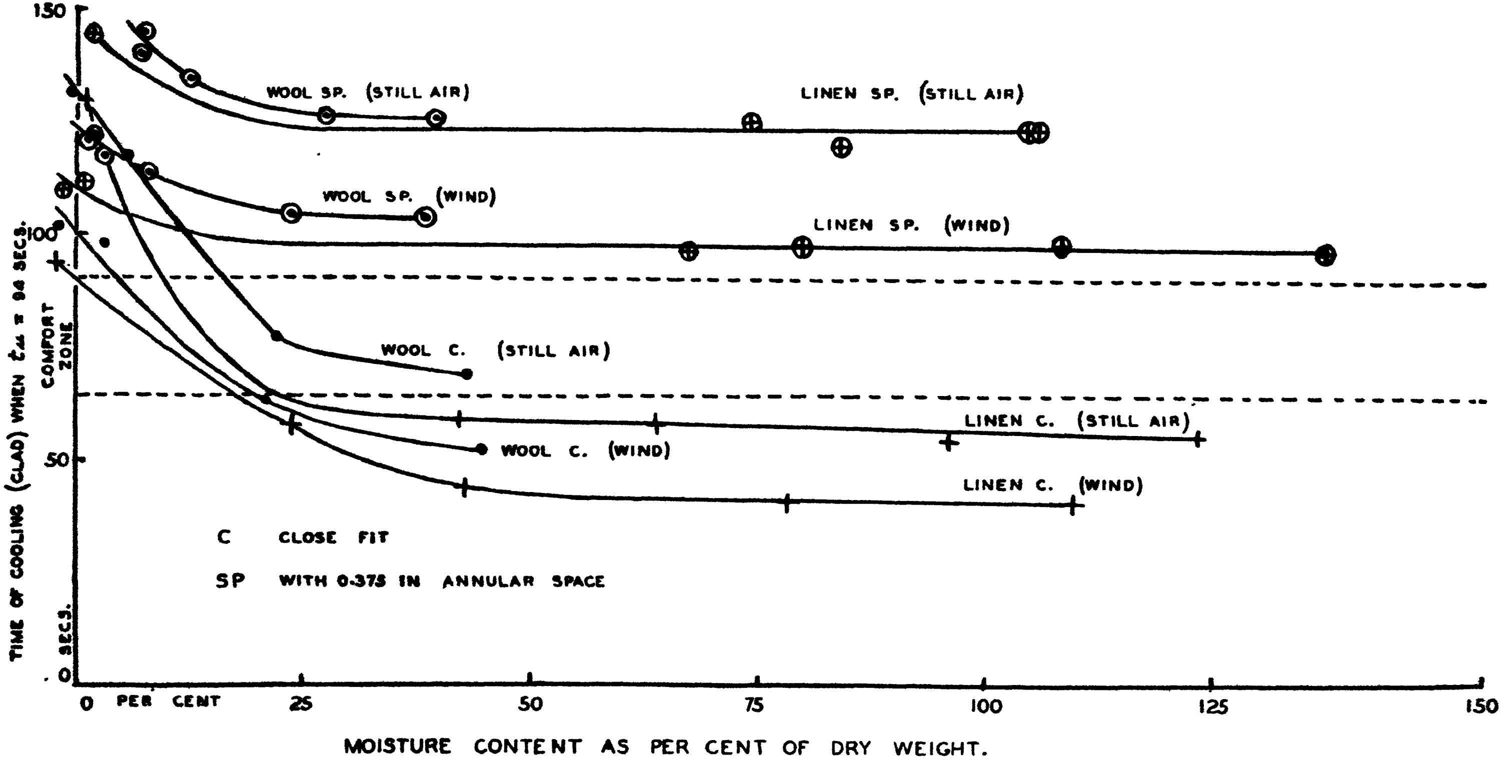

150
100
50
0 SECS.
TIME OF COOLING (CLAD) WHEN t_m = 94 SECS.
COMFORT ZONE
WOOL SP. (STILL AIR)
LINEN SP. (STILL AIR)
WOOL SP. (WIND)
LINEN SP. (WIND)
WOOL C. (STILL AIR)
LINEN C. (STILL AIR)
WOOL C. (WIND)
LINEN C. (WIND)
C CLOSE FIT
SP WITH 0·375 IN ANNULAR SPACE
0 PER CENT
25
50
75
100
125
150
MOISTURE CONTENT AS PER CENT OF DRY WEIGHT.

FIG 6

The method used for preparing the moist samples for the tests on effect of moisture content on insulation can be adapted for an investigation of the rate of absorption of the material from a wet surface on one side, while actually drying at the other side. This is the condition of a single garment worn on the perspiring body. For these tests the "close fit" samples of linen mesh (112 CL) and light wool (120 CL) were used. The cylinders were drawn over filter paper covered plugs of cottonwool. The latter were of equal weight and volume and were supplied with equal measured amounts of water to saturation. The plugs, with their fabric cylinders, were transfixed by long pins and suspended in similar positions in a constant temperature and humidity box. During the exposure to the box conditions the fabric cylinders were removed from the plugs and weighed in weighing bottles, at intervals. Thus while the plug was losing water continuously, the water content of the fabric was first increased by absorption alone, and, later, depended on the magnitude of the decreasing absorption and the rate of drying. Obviously the result depends on the rate of diffusion of water through the plug and the cloth, and so only applies to the experimental conditions, which were the same for the two materials. There were two separate experiments in still air for linen and wool, and a further experiment in which they were exposed to a wind of 4 ft. per sec. The temperature was constant at 18·5° C. throughout. Fig. 7 shows the difference in behaviour of the two materials. The maximum values of the moisture content, as per cent. excess of dry weight, and the times in which these amounts are attained in each case, are given in Table IV.

Table IV

	Linen Mesh (112 CL)		Wool (120 CL)	
	Still Air	Wind	Still Air	Wind
Maximum moisture content ...	84	88·5	9·5	5 (approx.)
Time, in hours	3	1·4	3	3 (approx.)

In still air the linen quickly attained its maximum moisture content, which was very much higher than that of the wool. The linen dried at a much quicker rate than the wool, and attained a lower moisture content finally. The wool picked up its maximum moisture in much the same time, but in the time of the experiment it had not dried appreciably from this condition. At the beginning, the linen sample almost immediately looked soaking wet and, at the end, looked quite dry as also did its cotton wool plug. The wool never looked quite soaking and did not look dry at the end. The plug under the wool looked quite wet at the end. The conclusion is that the wet body was effectively dried by the linen sample and was not by the wool. The effect of the wind was to cause the linen to attain its maximum and end points much more rapidly. In wind, the wool did not reach as high a maximum as it did in still air, and showed no sign of drying more rapidly.

A complementary set of tests was carried out on the rate of drying of the plugs, when the cloth coverings were absorbing while drying. The results of this set are shown graphically in Fig. 8. All the tests were made at the same small wind speed of 4½ ft. per sec. The effect of changing the temperature from 18·5° C. to 30° C., and also the effect of having an outer cover of dry, previously laundered cambric at a distance of ¼ inch from the inner cylinder are shown in Table V, in terms of the rate of drying of the plug. This rate is taken from Fig. 8, at 2 hours, as at this time the plugs had reached a steady rate of drying.

Table V

	Rate at 2 hours % per hour		Total Time to Dry	
	Linen Mesh	Wool	Linen Mesh	Wool
Single layer (18·5° C.) ...	44·5	8·5	Over 15 hrs.	Over 15 hrs.
,, ,, (30° C.) ...	79·5	52·0	5·5 hrs.	7·3 hrs.
With cover (30° C.) ...	46·0	46·0	8·5 hrs.	9 hrs. (approx.)

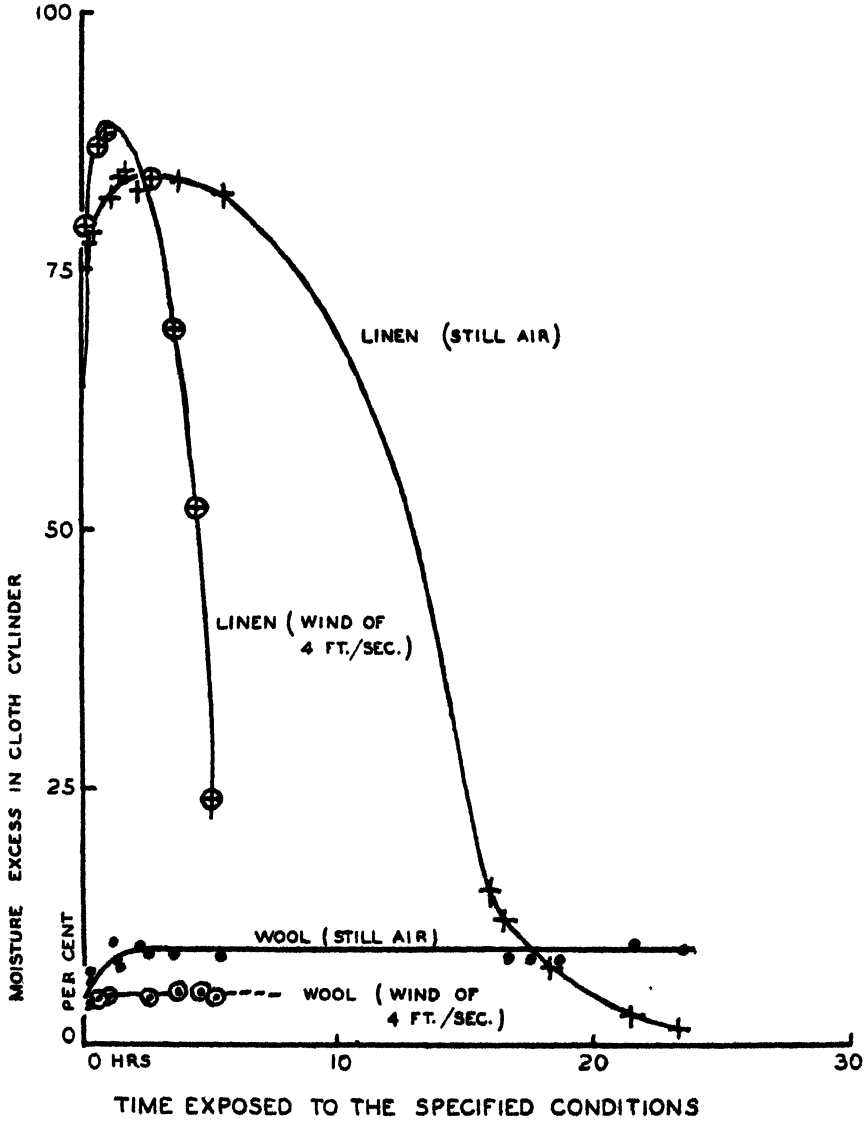


Fig. 7

At the higher temperature, the rates of drying were increased, the effect being more marked in the case of the plug covered with wool, the rate of drying of the wool covered plug always being much less than that of the other. The total time to dry was, of course, reduced in both cases. The effect of adding the cambric outer cover at the same temperature (30° C.), was to reduce the rates of drying in both cases. When provided with the outer cover, the rates of drying of the two plugs coincided over a considerable range of time.

These observations are of interest with regard to the conditions which garments of such materials may attain in wear under conditions liable to set

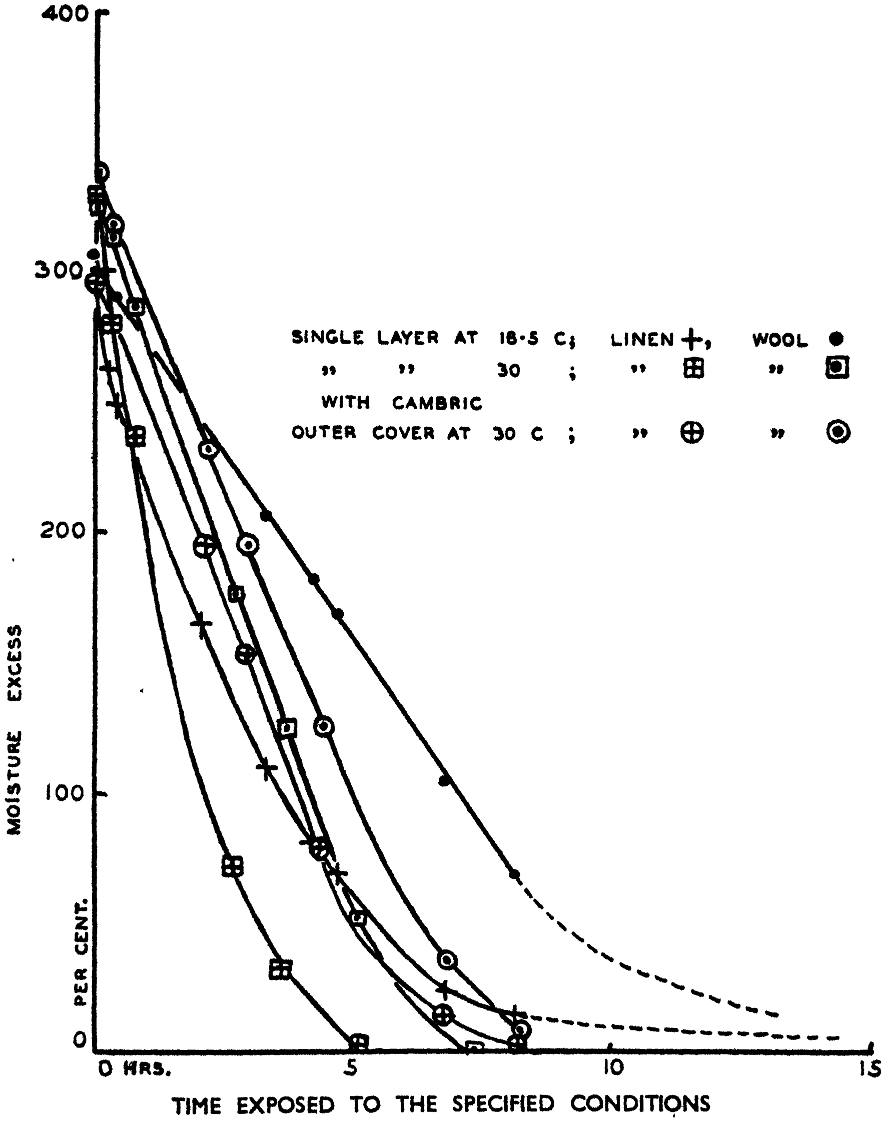


Fig. 8

up copious perspiration. First, if the moisture content of the wet plug may be considered as having some relation to the wetness of the skin, it may be inferred that a linen garment will tend to keep the skin dryer than a woollen one, which is very important as regards the feeling of comfort experienced. The observations of the moisture content of the covering show that the quicker drying of the plug is chiefly due to the greater amount of moisture absorbed by the linen. In practical wear other considerations are also of importance; the amount of moisture held may affect comfort by causing a chilled feeling when the body begins to cool off after strenuous exercise, and another point is that a damp garment when removed must be dry before being used again. Obviously what happens must depend on many conditions. Apparently under given conditions the linen covering will tend to hold much more water than the wool covering, but the skin will be dryer and the linen will not hold its moisture so long as the wool. No conclusion can be drawn from the actual figures as to what the body will feel. No doubt the temperature of the wet garment will be of importance, but if covered by a second or more layers of clothing, this must be in the neighbourhood of body temperature, and no feeling of chill should be felt. In addition, the effect of the moisture content on the heat-retaining power and permeability would be taken into account.

Nature of Material and Insulating Value

In Fig. 3 the insulation ratio is given for a number of typical fabrics of similar construction but of different materials, at a series of annular spaces. The curves are given for dry cloth (Figs. 3A and 3B), and for wet cloth (Fig. 3D) on dry kata. The effect of using the wet kata is also shown, for dry cloth (Fig. 3C), this case representing clothing worn on the perspiring body. From inspection of Fig. 3, the following conclusion may be drawn. The order of insulating value for the different materials remained the same, whatever the annular spaces when the cloth and the kata were dry. The order of increasing insulation value in these samples was artificial silk (114 CL) and linen mesh (112 CL) (equal), cotton mesh (113 CL), light knitted wool (120 CL), and heavy wool (121 CL). The last three mentioned have practically the same maximum values. In all five materials the maximum insulation value occurred at the same annular space. The maximum for the copper sheet was also at the same annular space, from which it may be inferred that the shape of the curve is determined by the volume of air enclosed in the annular space rather than by the nature of the material.

In the case of dry cloth, with wet kata, the maxima occurred at larger values of the annular space. In the case of wet cloth, with dry kata, the maxima occurred at still greater annular spaces. In the case of 120 CL wet and 113 CL wet, the maximum was not reached at the largest space tested.

It is obvious from all three sets of curves that the space at which a garment is worn from the body has more effect upon its value as an insulator than has the kind of material from which it is made, whether wet or dry, or whether the body is wet or dry. For example, the heavy knitted wool (121 CL) has the highest insulation ratio (1·287) of the fabrics tested and artificial silk mesh (114 CL) the least (1·1), when both are close fitting to the body. But if the artificial silk is worn with an average air gap of $\frac{1}{16}$th of an inch, its insulation is equal to that of the heavy wool at close fit. If an air gap of 0·325 of an inch were feasible, the artificial silk would be more insulating than the close fit wool in the ratio 1·53 to 1·287.

The effect of saturating the cloth is more marked at close fit, where its insulation is halved than at the maximum, where its insulation is only

Table VI

Specifications of all the Fabrics used in the Tests, and the results obtained

Ref. No.	Type of Fabric	Condition	Lea of Yarn	Yarn Twist Factor	Weight per sq. yd. ozs	Thick-ness mm.	Ends per inch		Insulation Ratio (t_c/t_u)		Initial Rate of Cooling (Degrees per sec.)
							Warp	Weft	Close Fit	Ann. space =0·375 in.	
112 CL	Linen mesh	Finished and laundered	80's flax ...	—	5·97	0·54	—	—	1·095	—	0·161
113 CL	Cotton mesh... ...	,, ,, ,,	30's single cotton	—	5·69	0·67	—	—	1·13	—	0·159
114 CL	Artificial silk mesh ...	,, ,, ,,	350 denier ...	—	6·58	0·432	—	—	1·032	—	0·172
115 CL	Cellular cotton (light)	,, ,, ,,	31's twofold ...	—	4·07	0·506	—	—	1·11	—	0·158
116 CL	,, ,, (heavy)	,, ,, ,,	21's twofold ...	—	4·83	0·66	—	—	1·088	—	0·148
120 CL	Knitted wool (light)	,, ,, ,,	124's twofold .	—	7·37	0·66	—	—	1·158	—	0·154
121 CL	,, ,, (heavy)	,, ,, ,,	62·5's twofold ..	—	10·21	0·83	—	—	1·15	—	0·14
29 CL	Plain weave 2½ lb. dry spun line flax yarn bleached ¾ white	Laundered	25's line ...	1·7	4·4	0·402	23·3	32·8	1·175	1·55	0·146
30 CL					4·9	0·405	28·9	32·8	1·17	1·552	0·158
31 CL					5·5	0·410	34·0	32·8	1·14	1·513	0·177
32 CL					6·56	0·404	43·3	32·6	1·095	1·483	0·215
33 CL					6·06	0·415	47·2	33·6	1·078	1·51	0·27
34 CL					6·36	0·421	49·8	33·7	1·042	1·51	0·221
35 CL					4·41	0·356	36·1	21·7	1·152	1·518	0·172
36 CL					5·05	0·376	37·9	25·3	1·103	1·489	0·171
37 CL					5·35	0·389	39·0	29·0	1·105	1·508	0·17
38 CL					—	0·415	39·8	38·2	1·092	1·533	0·214
39 CL					6·71	0·455	40·8	41·8	1·08	1·545	0·225
40 CL					6·59	0·356	40·3	43·5	1·062	1·51	0·228
75 C	Plain weave linen ...	Loomstate	40's line ...	2·1	4·71	0·287	53·5	54·3	1·097	—	0·156
75 CF	,, ,, ,, ...	Loomstate and finished			4·96	0·2	56·5	52·8	1·084	—	0·195
75 CFL	,, ,, ,, ...	Finished and laundered			5·07	0·28	58·0	54·3	1·063	—	0·161
75 CBL	,, ,, ,, ...	Bleached, finished, and laundered			3·97	0·266	58·25	51·8	1·106	—	0·125

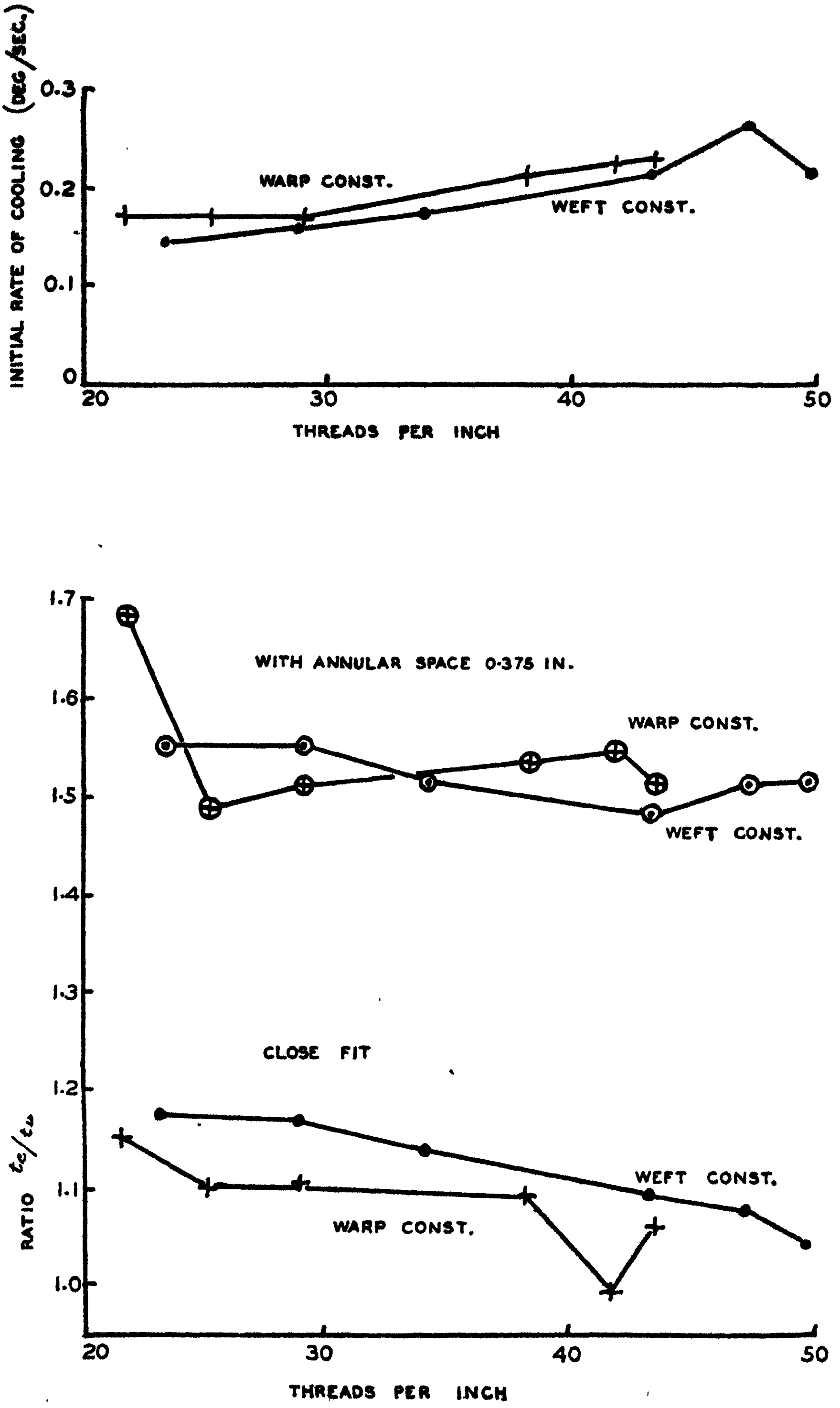

INITIAL RATE OF COOLING (DEG/SEC.)
0.3
0.2
0.1
0
WARP CONST.
WEFT CONST.
20
30
40
50
THREADS PER INCH
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
WITH ANNULAR SPACE 0·375 IN.
WARP CONST.
WEFT CONST.
CLOSE FIT
WEFT CONST.
WARP CONST.
RATIO t_e/t_u
20
30
40
50
THREADS PER INCH

Fig. 9

reduced from 1·65 to 1·15 or 30 per cent. Further, when the material is wet, differences in insulation due to kind of material are very small, all the curves lying close together. As an example of this, the ratio of the highest and lowest insulating values (heavy wool and artificial silk) when close fit and dry is 1·287:1·1 or 1·17. Taking an average cloth whose insulation lies between these extremes, the ratio of its insulation value when dry to that when wet is 1·2 : 0·4 or 3.

When the kata is wet, the curves are of the same characteristic shape. It may be noticed that any material tested had a higher protective value towards the perspiring body than towards the dry body.

Cold Feel

The effect of different materials, of similar construction, upon cold feel, was tested by the method already described, using the same set of mesh fabrics in air dry condition. The order of decreasing cold feel was—artificial silk mesh, linen mesh, cotton mesh, light cellular cotton, light wool, heavy cellular cotton, heavy wool. The initial rates of cooling only vary between 0·17 degree (F.) per sec. for artificial silk to 0·14 degree per sec. for the heavy wool. This very small difference in the figures corresponds to a very distinct difference in the feel as actually experienced by the hand.

Closeness of Weave and Insulation

Tests were carried out on a plain weave material, made from 2½ lb. dry spun flax yarn, bleached ¾ white, and manufactured in a series of settings. The material was always used in the air dry and laundered condition at 18·5° C. in still air. In a series of six of these fabrics the number of warp yarns varied from 23 to 50 threads per inch, the number of weft yarns remaining fixed at about 33 in each case. In a further series of six, the number of weft yarns per inch varied from 21 to 43, while the warp varied slightly from 35–40. In the first series (35–40 CL), the thickness increased, with increasing weft count, from 0·35 to 0·44 mm., as well as weight and apparent density. This is due to the greater bending of the warp to accommodate the increase of weft.[5] The textile analysis and the results of the tests on all fabrics are given in Table VI.

The values of the insulation ratio, t_e/t_u, were found for the members of these two series, both for close fit and for an annular space of 0·375 in. The latter was chosen as it was the actual size tested which gave the maximum valuation of the insulation ratio for all materials tested. In Fig. 9, the ratio t_e/t_u is plotted against weave. In the close fit condition the materials show a slight decrease in insulation with increased closeness of weave. When tested with the annular space, the insulation value was in all cases much higher; also the change in insulation between the extreme values of weave was very slight.

The inference to be drawn from these experiments is that the difference in insulation caused by a difference in weave of even 30 threads per inch is really quite small. This is particularly so when there is a space between the kata thermometer and the fabric. This applies to fabrics of not less than 20 threads per inch, either way.

Closeness of Weave and Cold Feel

These tests were carried out as already described and the two series of plain weave samples used for the insulation tests were again utilised. The results are shown at the top of Fig. 9, which shows that there is a slow continuous increase in cold feel with increasing closeness of weave. This may be attributed to the fact that as the closeness of weave increases there will be more fibre per unit area of cloth surface to come into contact with the warm kata surface. Comparing the two series, each as a whole, it will be noticed that the members of the set with increasing warp threads per inch give greater insulation, at close fit, and smaller cold feel than the corresponding members of the other set. This is probably due to the fact that the apparent densities of the first set mentioned were all less than those of the second. The conclusion is that there is a definite increase in cold feel with increase of ends per inch; the extreme values show very small differences but, as already remarked, they correspond to appreciable differences to the hand. If the above supposition as to the effect of the amount of surface fibre is correct, then it would be expected that the type of finish or the condition of the cloth (whether loomstate, finished or laundered) would have a definite effect on its cold feel.

The Effect of Finishing Treatment

Four samples of a plain woven linen cloth were tested for insulating value and cold feel, after different finishing treatments. The testing conditions were loomstate (¾ white); after finishing; after finishing and laundering; after being bleached to full white, finished and laundered. (See samples 75 C, CF, CFL, and CBL in Table VI.) Insulation was found to decrease through the first three conditions in the order named above. It then recovered completely, in the fully bleached sample, to the value obtained for the loomstate. These insulation changes are readily explained by referring to the weave changes through the stages of treatment. When a fabric is "finished" there is a weft shrinkage. There is a further weft shrinkage in laundering. Consequently there is an increase in the number of threads per inch in the warp in both cases, the number of weft threads per inch remaining sensibly constant. The insulation ratio follows this weave change as we have shown in the previous section. The fabric which was bleached before finishing and laundering, although showing the same amount of weft shrinkage as the others, showed fewer threads per inch weft way. This may be due to warp stretch. The effect was that the insulation ratio recovered to its loomstate value. In any case, apart from weave change, the bleaching process lowered the apparent density of the cloth and of the individual yarns. This would also tend to increase the insulation value obtained.

As regards the effect of cloth treatment on cold feel, there was a sharp increase from loomstate to finished condition, followed by a lowering to the loomstate value in the laundered condition. The fabric which had the additional bleaching treatment showed the smallest value of cold feel.

SUMMARY AND CONCLUSIONS

The results of experiments are described, in which a kata-thermometer is used to measure the heat insulating power and the "cold feel" of fabrics. The insulating value is expressed by the ratio of the times taken by the kata to cool over its graduated range when clad with the fabric and when unclad. Cold feel is expressed by the initial rate of cooling induced in the warm kata when the cloth is first applied.

Insulating Value of Fabric as affected by Physical Conditions

Annular Space—There is a value of annular space between the sample and the kata at which the insulation is a maximum, and this value was approximately the same for all materials tested, including wire gauze and copper sheet.

Air Movement—For any value of annular space and when an outer cover is added to the single layer of fabric, wind exerted its greatest effect on insulation at speeds from still air to a draught of 2 ft. per sec. The insulation was enhanced by the presence of an annular space in still air or at low wind speeds, but not at high speeds. At high speeds, all the materials tended to give the same small value of insulating power. When there was an outer cover, the nature of the material inside was of little significance. The change in wind speed from zero to 3 ft. per sec. caused a greater change in the insulating power of any material than that caused by change of material at any wind condition. By suitable adjustment of air movement or temperature, any material could be moved into or out of Hill's "comfort zone".

Moisture Content—The effect of increasing the moisture content of the fabric when single, or of the inner layer when double, whether close fit or having an annular space, above 75%, was negligibly small. Up to 75%, the insulating value decreased, more markedly so when close fitting. The effect of changing the moisture content of one material from zero to 75% was greater than the differences in insulating powers of different materials at any given moisture content.

Insulation of Kata as affected by Differences in Material, Cloth Structure, and Condition

Material—The insulating values of a number of different materials were determined, the values being fairly close at the annular space for maximum insulation. The insulating value of any material tested could be altered by spacing to a greater extent than the extreme difference in insulating values of all the materials taken at any annular space. This also applied when the kata was wet, and was more marked when the cloth was wet.

Small differences in cold feel were obtained and these agreed with the sensations experienced when the cloths were touched by hand.

Weave—The differences in insulating value (at close fit and with space for maximum insulation) caused by changes of up to 30 threads per inch, warp or weft, were small, particularly when there was an annular space. There was a definite increase in cold feel with increasing ends per inch, but the difference in extreme values was small.

Finishing Treatment—In the sample tested, the insulating power of a loomstate ¾ white fabric decreased after finishing but recovered after laundering. When the fabric was bleached to full white, finished and laundered, the insulation recovered to its loomstate value. The values of cold feel changed in the reverse directions.

The general conclusion to be drawn from the results is that the insulation provided for the kata thermometer was determined, in the main, by such conditions as annular space, air movement, the moisture content of the cloth, and whether single or double layers were used. The nature of the material in the cloth and its mode of construction exerted a relatively minor influence under every condition tested. That material which is chosen to give the most suitable value of insulating power under a given set of physical conditions will make the most comfortable garment, if it also keeps the perspiring skin dry by suitable absorption and ventilation.

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17—SOME PHYSICAL PROPERTIES OF KNITTED FABRICS

I—THICKNESS, WEIGHT, AND COMPRESSIBILITY

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SUMMARY

For a large number of samples, selected from a wide range of knitted fabrics, the thickness and weight per unit area have been measured. Two types of thickness measurer have been discussed and the number of readings necessary has been determined. The effect of pressure on the thickness of knitted fabrics was investigated in detail so that the best pressure for comparative experiments between fabrics could be employed. A pressure of ten grams per square centimetre was found to be generally suitable for comparison, but the lower pressure of one gram per square centimetre was more desirable for determination of the actual thickness. The ratio of thickness to weight was studied for the different types of fabric and, although the results are very diverse, some general inferences were drawn. The actual construction of the fabric has the greatest influence on this ratio; the material employed for the fabric appears to be a secondary consideration except that rayon fabrics generally tend to be thin. They are also, as a class, not very compressible on account of their lack of surface fibres and consequently compare most favourably if the thickness is measured under high pressure. Interesting results have been obtained by calculating the density of the fabrics and so forming an approximate idea of the proportion of the fabric space actually occupied by the fibres of which they are constructed.

INTRODUCTION

Very little is known about the physical properties of knitted fabrics, particularly their relationship to those of the better known woven cloths, and the purpose of this survey was an endeavour to discover and record some of these elementary characteristics. The properties selected for investigation were thickness and weight, since these two are fundamental and of primary importance, and the present paper is confined to a discussion of these two factors.

Since the range of knitted fabrics has now been extended to all classes of textile materials, by the gradual improvement of machinery and processes, the work necessary for a complete survey would be excessive. For this reason, the present investigation has been confined entirely to fabrics suitable for clothing purposes, in which weight and thickness are of equal importance with appearance, strength and other properties and not subservient to them as in fabrics for special purposes. Particular attention has been paid to the underwear fabrics, since this class of goods forms the largest part of the output of knitted wear.

In view of the variation of plain fabric that can be produced on one machine with the same yarn, by adjustment of the knitting mechanism, it was evident that measurements would not be sharply defined but would tend to be spread over ranges of values; the same class of fabric made by different manufacturers is not identical.

MEASUREMENT OF WEIGHT

The weight per unit area of each fabric was determined on a four-inch square sample cut in a hand screw press. Each sample was conditioned for three days and weighed in an atmosphere of temperature 73° F. and 70 per cent relative humidity. For convenience of comparison they have been converted into the accepted units of ounces per square yard.

MEASUREMENT OF THICKNESS

All thicknesses required in this work were measured on the instrument designed by Marsh[1] at the Wool Industries Research Association, by means of which the thickness of a fabric at any reasonable pressure may be determined. A small sample of fabric is attached to a wire frame and suspended vertically between two opposed circular vertical faces, each of one square centimetre area. One of these faces can be traversed horizontally by a fine screw, a dial gauge recording the traverse in thousandths of an inch. The other face is supported on the vertical arm of a freely mounted bell-crank, whose horizontal arm can be loaded with suitable weights. This system enables any convenient pressure to be applied to the fabric. When the upper arm is truly vertical, it makes a light contact with a stop and operates an electrical circuit. The difference in the dial readings when the fabric is between the faces and absent, at this contact, represents the thickness of the fabric at the pressure applied.

Great care was necessary in mounting the fabric specimens on to the wire frame, on account of the ease with which knitted fabrics can be stretched; this applies particularly to fabrics with a ribbed or similar structure. The least amount of tension required to hold the sample flat was used, and the thickness was measured as near the centre of the specimen as possible. This care was found to be very necessary, as excessive stretching might cause as much as 30 per cent. decrease in thickness of the fabric.

NUMBER OF OBSERVATIONS

The accuracy of the readings obtained by the use of the instrument was very good, control being possible to half a scale division, which was the limit of reading, but the results, of course, were subject to the usual errors of random sampling of the specimens from the fabric bulk. To form an idea of the number of readings necessary for a reasonable degree of accuracy, a large number of samples from one fabric was examined. A determination of this character is of greater importance for knitted fabrics than for woven ones since the irregularities are generally greater. This may be ascribed to various causes, e.g. low twist yarns are used; the yarns are not sized before knitting; the structure of the fabrics is naturally loose and open; surface fibres are a recognised part of the fabric; fabrics may be lightly brushed or raised and the surface is not cropped in any way. All these factors combine to produce a comparatively uneven surface.

The main investigation was made on a sample of good quality wool underwear fabric knitted from 2/28's yarn, scoured and finished with very light milling and brushing. A piece of this fabric was cut up into a large number of suitably sized specimens and one hundred of these was selected at random for the actual testing. The thickness of each sample was measured successively at six pressures in ascending magnitude, viz. 0·5, 1, 5, 10, 25, 100 grams per square centimetre. The statistical treatment of these results has followed the lines suggested by Turner[2] and the most important values are given in Table I. In Table II are shown the number of readings necessary at three different pressures for varying degrees of accuracy of the means, and of suitable probabilities or odds that such results are reliable. It will readily be seen that five per cent. accuracy can be obtained with good probability, for all pressures, by comparatively few readings but that greater accuracy requires an increasing number, the rise being particularly rapid in the case of the lowest pressure. It is evident that measurement at a lower pressure than ten grams per square centimetre will require a long time, and it is inadvisable to use a lower standard than this for the purpose of accurate comparisons unless ample time is available.

It is probable that much of the irregularity of thickness at low pressures is due to the effect of the surface fibres; their arrangement and individual rigidity are then the controlling factors and occasional rigid fibres will produce an apparently thicker fabric. A medium quality crossbred fabric, with a good covering of surface fibres, was tested for thickness at two pressures only, one and ten grams per square centimetre, 42 samples being taken for this purpose. The results of this experiment, treated as for those from the botany fabric, are shown in Table III. In Table IV are given the corresponding numbers of results required to satisfy the various conditions. The smaller variation of this crossbred fabric is at once evident from both Tables, and it is interesting also to note that the reduction in thickness caused by increasing the pressure from one to ten grams is much greater than for the botany fabric. The only possible explanation of these facts is that the actual substance of the crossbred fabric is really less thick than that of the botany fabric, but that its superior covering of surface fibres, of approximately uniform characteristics, gives it an apparently equal thickness at low pressures by the greater resistance of these fibres to compression.

Table I

Pressure (gms. per sq. cm.)	0·5	1	5	10	25	100
Range	50 87·5	44 80	38·5 59·5	35·5 54·5	33 49·5	29 40
Mean	63·54	56·90	46·35	42·91	39·38	34·14
Mean deviation	4·72	4·00	2·61	2·34	2·00	1·56
Standard deviation of single observation ...	6·06	5·34	3·45	3·14	2·70	2·11
Standard deviation of mean	0·61	0·53	0·35	0·31	0·27	0·21
Per cent. irregularity	7·44	7·04	5·64	5·45	5·08	4·57

N.B.—Coefficient of variation is approximately 1·253 × % irregularity.

Table II

	Degree of Accuracy											
	5%			3%			2%			1%		
Probability gms.	100	10	1	100	10	1	100	10	1	100	10	1
1 : 1	1	1	2	2	3	5	5	6	10	18	25	40
10 : 1	5	7	10	12	17	28	28	37	63	109	153	251
22 : 1	7	9	15	18	25	40	39	55	90	156	218	360
55 : 1	9	12	16	24	33	55	53	75	123	212	298	490
140 : 1	12	16	26	31	44	71	70	97	160	277	390	640

Table III

Pressure (gms. per sq. cm.)	1	10
Range	49 68·5	30 40·5
Mean	58·46	35·83
Mean deviation	4·15	1·67
Standard deviation of single observation ...	4·98	2·09
Standard deviation of mean	0·76	0·32
Per cent. irregularity	7·10	4·66

Table IV

		DEGREE OF ACCURACY											
		5%			3%			2%			1%		
Certainty ...	gms.	100	10	1	100	10	1	100	10	1	100	10	1
1 : 1 ...	...	–	1	2	–	2	4	–	4	9	–	10	33
10 : 1 ...	...	–	4	9	–	11	23	–	25	52	–	96	206
22 : 1 ...	...	–	6	12	–	16	33	–	35	75	–	140	297
55 : 1 ...	...	–	8	16	–	21	45	–	48	101	–	190	405
140 : 1 ...	...	–	10	21	–	28	59	–	62	132	–	247	528

A comparison was also made with a woven wool material in the form of a heavy overcoating. This fabric had been heavily milled, raised and cropped, and finished under heavy pressure so that its surface "skin" of fibres was very thin. The mean thicknesses measured at the above two pressures were 83·3 and 71·8 thousandths of an inch respectively, showing that the compression of this fabric was small. Further, the variation found was also small, indicating that, at a pressure of ten grams per square centimetre, ten readings were sufficient for two per cent. accuracy of the mean with a certainty of 55 to one.

The extreme example is furnished by the rayon fabrics which, of course, have no surface fibres. Tests of five fine rayon fabrics, warp-knitted, showed that the range rarely extended further than one half a thousandth of an inch on either side of the mean and the above accuracy of two per cent. with 55 to one certainty necessitated only four readings at the lowest pressure. Further, the decrease in thickness caused by increasing the pressure from one to ten grams never exceeded two thousandths of an inch.

Thickness/Pressure Relations

From the results already quoted it seems evident that the thickness of any fabric cannot be adequately expressed by a single figure, and that the pressure at which the measurement was made must also be quoted. For a complete description, the thicknesses at a number of pressures are necessary and they can be conveniently shown as a curve as suggested by Marsh (*loc. cit.*). It should be noted that the form of the curve can be accurately determined on a smaller number of samples than is necessary for absolute values of thickness, since the successive readings of each set are made on the same sample and are, therefore, correlated. Typical curves for plain knitted fabrics in wool, cotton and rayon are shown in Fig. 1.

The curve for wool flattens out only slowly with increasing pressure, while the corresponding curve for rayon has a more pronounced change of direction at about one gram per square centimetre; the cotton gives a curve very similar to that for wool. The length of the steep left-hand portion of the curves gives some indication of the amount of surface fibres on the fabric. When examining these curves, it should be remembered that the greater thickness of the wool fabric will tend to give its curve a steeper slope at all points than the rayon curve, because the actual compression will always depend on the initial thickness.

Use of the Roller Caliper

Instruments of this type have been frequently used for the measurement of fabric thickness and an account of some experiments made with such a caliper may be of interest here. The particular instrument used consists of a framework with a horizontal flat face on which the fabric rests. The frame carries a short pivoted lever; at one end is a roller which rests on the upper face of the fabric, while the other end is a pointer which moves over a fixed quadrant scale and records the extent to which the roller is raised by the cloth, which is the apparent thickness.

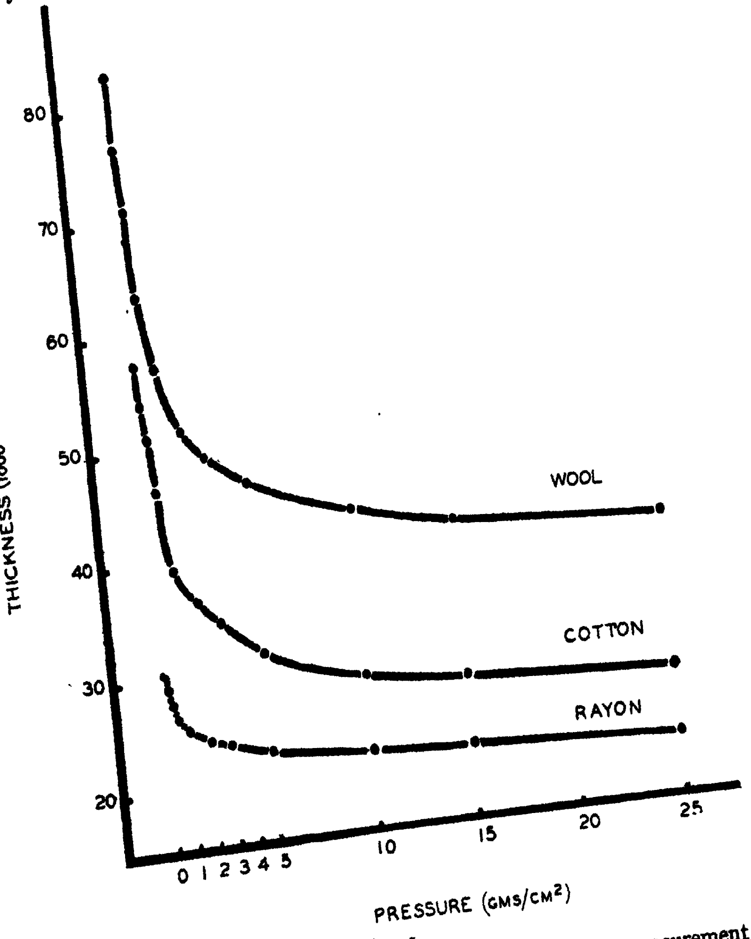

Fig. 1

The only recommendation of this method is the speed of measurement, which enables a large number of readings to be taken for a fabric. Serious disadvantages arise from the use of a circular roller for contact with textile materials since the area of contact depends on the extent to which the roller sinks into the fabric; this means that the pressure at which the measurement is made depends on the degree of compressibility of the material and will vary from one fabric to another. Further, the thickness recorded is measured to the lowest point of the roller and is less than the true value at the particular pressure. By observation, the area of contact was found to vary between 0·5 and 1·4 square centimetres, the resultant pressures being respectively 130 and 46 grams per square centimetre. These limits have been confirmed by measuring fabrics on the roller caliper and on the standard instrument, increasing the pressure on the latter until the same thickness was recorded on both.

These pressures are, of course, too high for the measurement of fabric thicknesses and the use of this instrument should be confined to comparative determinations on similar types of fabric only. It seems that the performance of this instrument for textile work could be greatly improved by replacement of the roller with a horizontal flat surface of smaller weight.

Description of Samples

When selecting a series of samples for the purpose of a survey of this nature the greatest difficulty lies in keeping the numbers down to a manageable limit. It is desirable that all abnormal fabrics should be omitted as they give exceptional results, e.g. fabrics knitted from yarn too thin or too thick for the gauge of the machine. The only real test for this quality is that a fabric shall be a commercial production.

A comprehensive range was included, both in regard to the materials used and to the methods of knitting, and all the fabrics are actually in use in commerce. A small number of speciality samples was chosen, each of a definite type, for purposes of comparison. The restrictions reduced mainly the number of fancy outerwear fabrics selected, leaving chiefly underwear, plain outerwear and hose fabrics for consideration. The chief materials used were cotton, rayon and wool, both separately and in combination as plated fabrics; no mixture yarns were investigated.

The basic types of stitch used for the fabrics were plain, one and one rib, and interlock. Other types introduced were half-cardigan, tuck-stitch, jacquard, and plain warp-knitting, with two samples in the simplest "purl"-stitch. Ten samples of cellular fabrics, woven and knitted, were also included for comparison. The knitted fabrics were produced on well-known types of machinery such as—Blackburn plain and rib, Wildman, Minotaur, Scott & Williams rib, "B5", "K", Terrot loop-wheel, Jacquard. The thicknesses range from thirteen to one hundred and thirty-five thousandths of an inch and the weights from 2·18 to 13·34 ounces per square yard. The actual distribution of these fabrics is shown in Table V.

Table V

	Wool	Cotton	Rayon	Wool/ Cotton	Rayon/ Cotton	Rayon/ Wool	Spun Silk/ Wool
Plain	7	7	4	6	3	2	1
1 × 1 Rib ...	4	6	2	–	1		
Interlock ...	2	7	2	–	–		
Half-cardigan	–	2	–	–	–		
Tuck-stitch ...	1	–	2	–	–		
Jacquard ...	2	–	–	–	–		
Warp-knit ...	–	–	6	–	–		
Purl-stitch ...	2	–	–	–	–		
Fleecy	–	1	–	–	–		
Cellular woven	–	8	–	–	–		
Cellular knitted	–	1	–	–	1		

RESULTS

The actual results of all measurements are given in detail in Table VI. For convenience of examination the results have been arranged in groups, first according to fabric structure and second according to material. The samples in each class are arranged in order of increasing weight. It is difficult to appreciate the value of the results without actually handling the samples but a brief description has been included in the third column. Weights are given in the fourth column in ounces per square yard. The fifth and sixth columns, marked (*a*) and (*b*) respectively give the actual thicknesses in inches at pressures of one and ten grams per square centimetre respectively. The last two columns, also marked (*a*) and (*b*), give the values of the thickness weight factor calculated respectively from the thicknesses in columns (*a*) and (*b*). This factor is the ratio of thickness to weight multiplied by one hundred, an index for a fabric suggested by Davis[8] in an earlier survey of this problem.

As some small indication of the relative merits of knitted and woven goods, seven samples of the latter class, two of wool and five of cotton, have been measured and the results included at the end of the list.

Table VI

Class	Sample No.	Description	Weight	Thickness (*a*) 1 gm./cm.^{2}	Thickness (*b*) 10 gm./cm.^{2}	(*a*) $\frac{100T}{W}$	(*b*) $\frac{100T}{W}$
Plain—							
Wool	26	Fine, Botany	3·56	0·035	0·021	0·98	0·59
	88	Medium; crossbred	6·06	0·058	0·036	0·96	0·59
	72	Fine; 2/54's Botany	6·26	0·040	0·030	0·64	0·48
	23	Medium; Botany...	7·17	0·061	0·046	0·85	0·64
	71	Medium; 2/28's Botany	9·26	0·057	0·043	0·62	0·46
	21	Coarse; crossbred...	9·82	0·056	0·044	0·57	0·45
	22	Coarse; crossbred...	11·39	0·078	0·058	0·69	0·51
Cotton	27	Fine	2·80	0·025	0·016	0·89	0·57
	73	Fine; 2/60's merc.	3·78	0·031	0·020	0·82	0·53
	10	Fine; 1/20's	4·16	0·042	0·028	1·01	0·67
	14	Medium; 1/16's	4·90	0·040	0·029	0·82	0·59
	11	Medium; 2/30's	5·46	0·051	0·034	0·94	0·62
	24	Coarse	6·52	0·059	0·040	0·91	0·61
	4	Coarse; 1/8's	6·61	0·055	0·042	0·83	0·63
Rayon	17	Fine; 200 den.	2·95	0·024	0·017	0·81	0·58
	16	Fine; 150 den.	3·46	0·020	0·016	0·58	0·46
	9	Medium; 2/150 den.	4·07	0·030	0·022	0·74	0·54
	5	Medium; 450 den.	4·52	0·026	0·022	0·58	0·49
Plated—							
Wool/Cotton							
	28	Fine	4·90	0·033	0·022	0·69	0·45
	54	Medium; 24's/14's	6·87	0·054	0·041	0·79	0·60
	25	Medium	8·56	0·055	0·043	0·64	0·51
	51	Medium; 26's/9's...	8·76	0·063	0·042	0·72	0·48
	52	Medium, 24's/10's	8·85	0·063	0·047	0·71	0·53
	53	Medium; 22's/9's...	10·32	0·071	0·055	0·69	0·53
Rayon/Cotton							
	15	Medium; 150 d/40's	3·87	0·038	0·025	0·93	0·65
	74	Medium; 150 d/36's	4·72	0·036	0·025	0·76	0·53
	63	Medium; 150 d/40's	5·69	0·044	0·028	0·77	0·49
Rayon/Wool							
	75	Fine; 100 den/70's	4·16	0·030	0·021	0·72	0·50
	30	Fine-medium	6·20	0·043	0·031	0·70	0·50
Spun Silk/Wool							
	29	Fine	5·25	0·036	0·028	0·69	0·53

Table VI—*continued*

Class	Sample No.	Description	Weight	Thickness (*a*) 1 gm./cm.^{2}	Thickness (*b*) 10 gm./cm.^{2}	(*a*) $\frac{100T}{W}$	(*b*) $\frac{100T}{W}$
1 × 1 *Rib*—							
Wool	32	Medium; Botany ...	4·72	0·044	0·034	0·93	0·72
	55	Medium; 1/44's Botany ...	5·05	0·034	0·027	0·67	0·55
	76	Medium; 1/32's Botany ...	5·69	0·056	0·047	0·99	0·83
	31	Coarse; Botany	6·52	0·058	0·045	0·86	0·69
Cotton	56	Medium; 1/30's	4·01	0·044	0·036	0·10	0·90
	33	Medium; 1/30's	4·64	0·041	0·032	0·89	0·69
	57	Medium; 1/30's	4·90	0·044	0·034	0·90	0·69
	78	Medium; 1/26's	5·96	0·050	0·038	0·84	0·64
	1	Coarse; 1/16's	6·05	0·059	0·050	0·98	0·83
	13	Very coarse; 1/8's ...	10·56	0·080	0·061	0·76	0·64
Rayon	79	Fine; 150 denier	3·72	0·022	0·020	0·59	0·54
	58	Fine; 150 denier	4·37	0·026	0·024	0·59	0·55
Rayon/Cotton	77	Medium; 150 d/28's ...	4·92	0·051	0·043	0·04	0·88
Interlock—							
Wool	82	Heavy; 1/45's Botany ...	6·81	0·053	0·043	0·78	0·63
	81	Heavy; 1/38's Botany ...	8·03	0·073	0·053	0·91	0·66
Cotton	85	Very fine; 1/80's Eg. ...	2·66	0·035	0·027	1·32	0·02
	61	Fine; 1/60's	3·22	0·034	0·027	1·06	0·84
	84	Fine; 1/48's Amer. ...	4·34	0·041	0·034	0·94	0·78
	34	Medium; 1/40's	4·90	0·042	0·032	0·86	0·65
	60	Coarse; 1/30's	5·25	0·041	0·034	0·78	0·65
	83	Very coarse; 1/26's ...	6·87	0·048	0·040	0·70	0·58
	59	Very coarse; 1/24's ...	7·15	0·048	0·036	0·67	0·50
Rayon	62	Fine; 125 denier	3·60	0·016	0·014	0·44	0·39
	86	Fine; 100 denier	5·05	0·023	0·021	0·46	0·42
Half-cardigan—							
Cotton	80	Coarse; 1/14's	7·31	0·072	0·060	0·98	0·82
	2	Very coarse; 1/8's ...	10·53	0·078	0·070	0·74	0·66
Tuck-stitch—							
Wool	64	Coarse; 1/24's	5·40	0·064	0·048	1·19	0·89
Rayon	87	Fine; 150 denier	2·72	0·028	0·021	1·03	0·77
	6	Medium; 450 denier ...	3·92	0·059	0·034	1·25	0·87
Jacquard—							
Wool	8	Medium; 2/44's	6·61	0·062	0·051	0·94	0·72
	7	Medium; 2/40's	9·06	0·094	0·073	1·04	0·81
Fleecy—							
Cotton	12	Coarse; 1/20's, 1/30's, 1/6's Condenser ...	8·90	0·104	0·071	1·17	0·80
Purl-stitch—							
Wool	89	Coarse	7·34	0·176	0·130	2·40	1·77
	90	Coarse	7·85	0·200	0·135	2·55	1·72
Warp-knit—							
Rayon	3	Coarse; 300 denier ...	13·34	0·064	0·059	0·48	0·44
	95	Fine; lace net; 80 den. ...	2·18	0·025	0·023	0·17	1·06
	94	Fine; pique; 60 den. ...	3·52	0·023	0·021	0·65	0·61
	93	Fine; pinhole stripe; 60 denier	3·54	0·015	0·013	0·42	0·38
	91	Fine; plain; 120 den. ...	3·84	0·016	0·015	0·43	0·40
	92	Fine; hairline stripe; 80 denier	4·02	0·021	0·019	0·54	0·49
Cellular Woven—							
Cotton	45	Pattern 931	3·81	0·040	0·034	1·05	0·89
	46	,, 1601	3·96	0·038	0·033	0·96	0·83
	41	,, 1616	4·37	0·048	0·040	1·10	0·92
	43	,, 88	4·58	0·043	0·036	0·94	0·79
	42	,, 1080	5·34	0·046	0·038	0·86	0·71
	47	,, 14AE	5·61	0·050	0·041	0·89	0·73
	48	,, 11EA	6·20	0·058	0·052	0·94	0·84
	44	,, 11AW	6·79	0·062	0·055	0·92	0·81

Table VI—*continued*

Class	Sample No.	Description	Weight	Thickness (a) 1 gm./cm.²	Thickness (b) 10 gm./cm.²	(a) 100T/W	(b) 100T/W
Cellular Knitted—							
Cotton	49	Ribbed tuck	5·05	0·056	0·046	0·11	0·91
Rayon/Cotton	50	Ribbed tuck	4·90	0·050	0·043	1·02	0·92
Woven—							
Wool	101	Heavy overcoating ...	14·47	0·083	0·072	0·57	0·50
	102	Worsted suiting	9·43	0·046	0·032	0·49	0·34
Cotton	104	2 × 1 Twill	4·91	0·033	0·022	0·67	0·45
	106	2 × 2 Twill	4·94	0·037	0·024	0·76	0·48
	103	1 × 1 Twill	5·14	0·019	0·013	0·37	0·26
	107	2 × 2 Twill	6·00	0·037	0·024	0·62	0·40
	105	2 × 2 Twill	6·69	0·041	0·031	0·61	0·46

DISCUSSION OF RESULTS

The extreme range of weight shown by the knitted samples is from 2·18 to 13·34 ounces per square yard. Both limits are actually supplied by the rayon warp-knitted fabrics, but the plain knitted fabrics vary to nearly the same extent and also cover the intermediate range thoroughly. It may be noted that the cotton fabrics in this class vary generally from light to medium and the wool from medium to heavy, although the same is not true for the 1 × 1 ribs. The weight range for useful knitted fabrics is evidently less than that for woven materials.

To a great extent the thicknesses in each class increase with the weights although generally not so rapidly. All the rayons are the thinnest, grouped about 0·020 inch, the plain fabrics are intermediate, and the more developed stitches in wool and cotton are the thickest. The interlock fabrics are rather finer than the plain and are the most uniform as a group. This is controlled by the fact that the structure is very firm and that there is only one gauge of machine for all the fabrics in this class, which restricts the use of coarse yarns. By far the thickest materials are the two purl-stitch outerwear fabrics, which are, of course, a class entirely on their own with regard both to bulkiness and to openwork of stitch. It may be noted that the few woven samples included are thinner than the corresponding knitted plain fabrics of similar weight.

It is evident that, within certain limits, a knitted fabric can be constructed to any specification of weight and thickness by using the appropriate material and structure; consequently, consideration of these two factors separately gives little information about the fabric. For this reason, it has been found desirable to combine them in the form of the "index" already referred to, as given in the final columns of Table VI. This index has some practical merit in that it helps to convey an idea of the compactness of a fabric. If the weight and thickness in a class increased regularly together, this index would remain constant and would clearly define the class of fabric.

Unfortunately, this was found not to be exactly true, the index for any class actually spreading over a considerable range. In the case of the interlock fabrics, which form a very complete series, the index falls regularly as the weight increases. This may be attributed to the single gauge of machine available, which really makes the coarser fabrics too dense and heavy, while the finer fabrics are too gauzy and light. The truly balanced fabric is No. 34 at the centre of the range. For the manufacture of plain fabrics a wide range of different gauge machines is available and no fabric is far unbalanced. The effect is shown by the range of the index being more restricted and fluctuating irregularly. A large increase in the index can be noticed as the stitch construction is developed. The 1 × 1 rib fabrics, half-cardigan, jacquard and tuck-stitch are definitely distinguished from the plain fabrics, while the purl-stitch are the highest class of all. The woven fabrics generally give a lower index than the corresponding plain knitted fabrics, while the cellular fabrics as a class are slightly superior to the 1 × 1 rib stitch.

The index, of course, depends on the pressure at which the fabric thickness was measured and two such sets of values have been given. From inspection of the results it appears to be largely immaterial which set is used for comparative purposes in a class; from one class to another there may be some difference in compressibility at the pressures used, depending mainly on the fabric structure. Figs. 2 and 3 illustrate the difference in index obtained, at the two pressures used, for the 1 × 1 rib and interlock fabrics respectively. These indices are arranged in progressive order, the pairs of values on each ordinate relating to the same fabric.

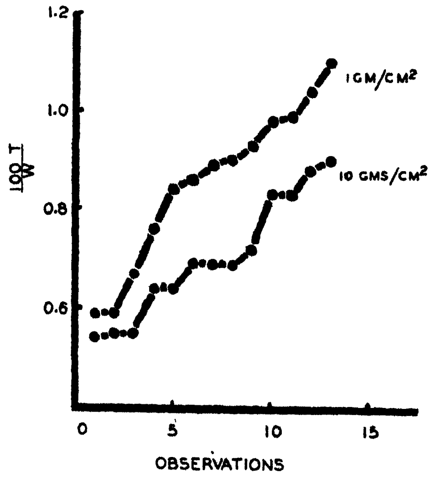

Fig. 2

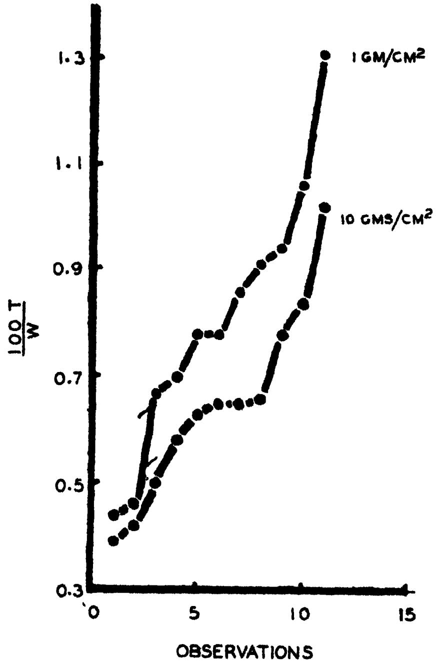

Fig. 3

In each diagram the two lines follow approximately similar paths with the upper one showing a steeper slope as expected. The relative compressibilities of the plain, 1 × 1 and interlock fabrics are shown better on one diagram in Fig. 4. This is obtained by plotting for each fabric the index at 1 gram per square centimetre as ordinate and the other index as abscissa. A line through the origin at 45° with both axes represents no compression and the slope of the line joining each point to the origin is a measure of the compressibility of each fabric.

This opportunity is taken of expressing thanks to the Wool Industries Research Association for their help and advice in the course of this investigation.

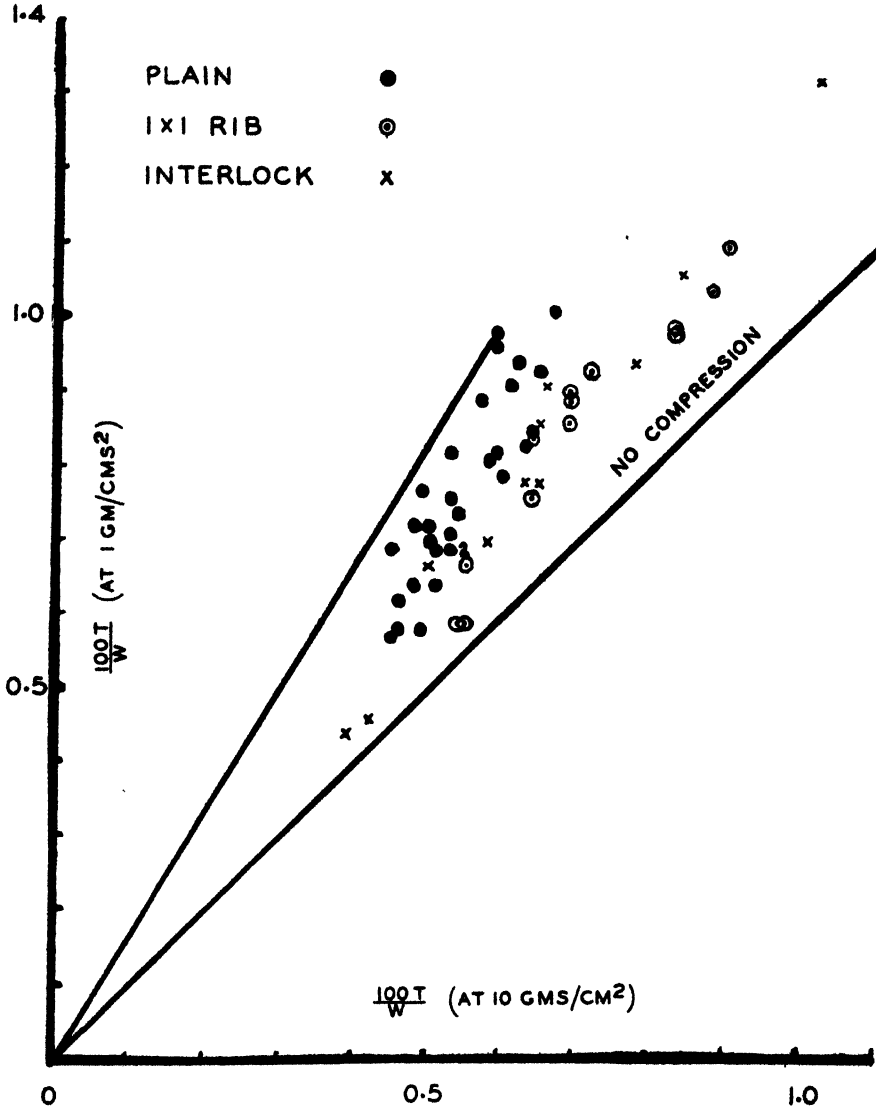

Fig. 4

APPENDIX

The index calculated above has an additional value. It will be seen from the definition of W as ounces per square yard that the index has the dimensions of the reciprocal of density ($M^{-1} L^3$). It can, therefore, be used to calculate the density of the fabric in ounces per cubic inch.

Thus, a square yard of fabric weighs W ounces and its volume is $36 \times 36 \times T$ cubic inches.

Its density is $\frac{W}{36^2T}$ oz. per cu. in.

Since the index is $\frac{100T}{W}$, it follows that

$$\text{density} \times \text{index} = \frac{W}{36^2T} \times \frac{100T}{W} = \frac{100}{36^2} = 0{\cdot}077$$

i.e. the density is obtained by dividing the index into 0·077. The relative density is more useful and can be calculated by dividing the density by the weight in ounces of a cubic inch of water, viz. $\frac{1000}{1728}$ oz.

$$\text{Then, relative density} \times \text{index} = \frac{100}{36^2} \div \frac{1000}{1728} = 0{\cdot}1333.$$

The relative density of a fabric can thus be obtained rapidly from its index by dividing the latter into the constant 0·1333.

For the plain cotton fabric No. 10, using the index 0·67, the relative density is 0·20. Further, assuming the relative density of cotton to be 1·5, it is possible to form an idea of the approximate proportion of the fabric volume actually occupied by cotton fibres. For the above fabric, the proportion is 0·20/1·5, or 13 per cent.

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18—THE USE OF TRYPSIN FOR THE DETERMINATION OF THE RESISTANCE OF WOOL FIBRES TO BACTERIAL DISINTEGRATION

By R. Burgess
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The disintegration of the wool fibre into its component elements, epithelial scales and cortical cells (Figs. 1 and 2) by proteolytic bacteria has been described by many workers. It is desirable, however, that another method be available, preferably one which more rapidly effects this fibre breakdown, for the following reasons—

(*a*) Owing to the incompleteness of our knowledge of the bacterial phenomena, to rapid changes in reaction and to the necessity for optimum aeration, the process cannot always be effected in culture with the same exactitude.

(*b*) The determination of variations in the resistance to bacteria of wools either possessing different degrees of soundness or treated with certain antiseptics would be facilitated.

(*c*) The resistance of the fibre to proteolytic enzymes is considered to be a more important desideratum than the inhibition of bacterial development produced by an antiseptic present in or on the fibre.

To this end the possibility of using some commercial proteolytic ferments has been explored. Exposure of wool to the action of certain enzymes is already known to effect fibre disintegration. Meunier *et al.*[5] found that wool swollen in alkaline solution is attacked by pancreatic enzymes, while Gabriel[3] cites Dych (1910) as patenting a process for removing the epithelial scales of wool fibres with pepsin or pancreatin and also records the work of Keys who showed that pepsin is capable of breaking down the fibre.

Experiments with Trypsin and Pepsin

Expt. 1. Portions (0·1 g.) of wool material were immersed in plugged test tubes containing buffered solutions of trypsin (B.D.H.), pepsin (B.D.H.) or the filtered solution from a three weeks' old culture of bacterially-decomposing wool (urine-contaminating Micrococcus spp.) and kept at 35° C. A control series, exposed in a water bath at 100° C. for 5 minutes to inactivate the enzymes, was also set up. Samples of wool treated with Eulan N, which confers some protection against bacteria, were included.

The disintegrating power of the trypsin solution compared with that of the bacterial solution is obviously great. Chlorination predisposes the wool to disintegration, whereas chrome-eulanisation has a protective action. The results of Dych and Keys with pepsin are also confirmed.

Expt. 2. A further series, rendered more comprehensive by inactivating bacteria by the addition of a little toluol gave interesting results. The test tubes were corked.

The non-participation of bacteria in the presence of toluol was confirmed by microscopic examination and cultural tests. In certain cases, however, the continued development of these organisms evidently contributed to the disintegrating process.

The superiority of the commercial enzymes over the bacterial and the modification in the effect due to previous chlorination or Eulan N treatment are again apparent.

Table I

The Effect of Enzymes on Wool at 35° C. Incubation 5 days

0 = No fibre disintegration.
+ = Slight ,,
++ = Pronounced ,,
+++ = Severe ,,
++++ = Very severe ,,

SOLUTION	Scoured 60's Botany top	Chlorinated and milled hosiery fabric showing notable superficial damage to fibres (heavily treated)	Dress cloth commercially dyed in a chrome bath containing 3% Eulan N and finished in the customary way	Commercially chlorinated woven baby bag material, laboratory treated with 1% Eulan N
5 cc. of 0·5% aq. trypsin 5 cc. of *p*H 8·0 buffer[4]	+++	++++	+ (very slight)	++++
Do. heated for 5 mins. in a water-bath at 100° C. ...	0	+	0	0
5 cc. of 0·5% aq. pepsin 5 cc. of *p*H 1·4 buffer[6]	++	+++	0	++++
Do. heated	0	0	0	0
5 cc. of filtered (paper) bacterial culture 5 cc. of *p*H 7·0 buffer[8]	+	++++	0	+++ (fairly severe)
Do. heated	0	0	0	0

Buffer Solutions

(*a*) *p*H 8·00	... 0·10 M Potassium di-hydrogen phosphate		46·5 cc.
	... 0·05 M Borax		53·5 cc.
(*b*) *p*H 1·42	... 0·1 M Di-sodium hydrogen citrate ...		20·0 cc.
	0·1 M Hydrochloric acid		80·0 cc.

Experiments with Trypsin

Expt. 3. *The Effect of Different Concentrations of Trypsin*—Similar portions of scoured botany top were exposed at 35° C. to equal parts of trypsin solution and buffer, together with a little toluol and examined at intervals. Compared with controls, which showed no disintegration, a concentration of 0·2% trypsin gave marked disintegration in 24 hours; 0·1% gave considerably less, but the effect of higher strengths was not appreciably greater. As incubation time extended, the relative effect of the higher strengths (0·4-1·0%) became somewhat more marked but for the subsequent experiments it was decided to adopt the 0·25% concentration previously used.

EXPT. 4—COMPARISON OF THE EFFECT OF TRYPSIN AND WOOL-DECOMPOSING BACTERIA

Microscopically the trypsin solution and the bacterial culture produce disintegrations of essentially the same type, the former being, however, considerably more rapid. If, therefore, by a comparative test of the effect of both agents on a series of different wools, further correlation can be obtained, the more rapidly acting trypsin solution may be held to simulate in less time the action of bacteria. Its function will also be independent of some of the as yet unavoidable irregularities which sometimes occur in the case of bacterial culture solutions.

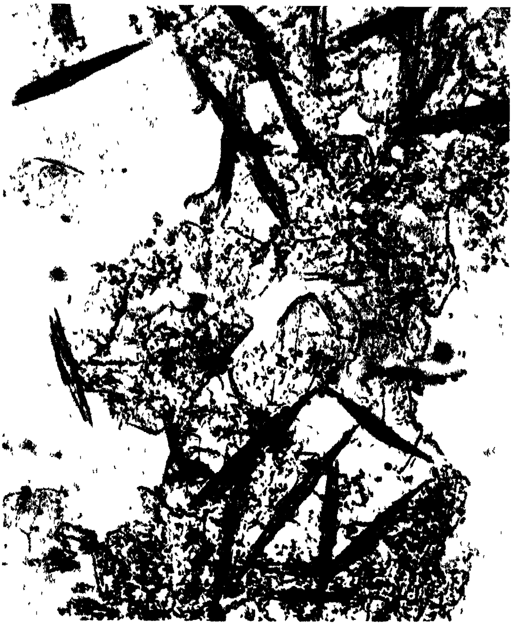

FIG. 1

Epithelial scales and a few cortical cells isolated from wool by retting with *B mesentericus ruber*

300

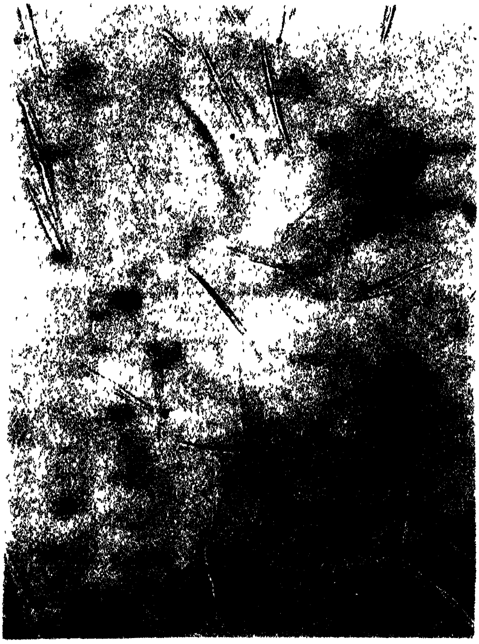

FIG. 2

Cortical cells, some of which are showing evidence of thinning (decomposition?). Isolated by trypsin solution

× 200

Table II

The Effect of Enzymes and Bacteria on Wool at 35° C. Incubation 6 days

0 = No fibre disintegration.
+ = Slight ,,
++ = Pronounced ,,
+++ = Severe ,,
++++ = Very severe ,,

SOLUTION	Scoured 60's Botany top	Chlorinated and milled hosiery fabric showing notable superficial damage due to rather heavy treatment	Woven papermakers' felt, laboratory treated with 3% Eulan N	Papermakers' felt not treated with Eulan N
Trypsin solution as in Expt 1	++++	++++ (extremely severe)	+ (fairly pronounced)	++++
Do. plus toluol ..	++ (very pronounced)	++++	+	++++
Do heated as in Expt 1	+ (very slight)	++ (very pronounced)	0	+
Do. * heated plus toluol	0	0	0	0
Pepsin solution as in Expt 1	++	++++	+	+++
Do. plus toluol . .	++ (very pronounced)	++++	+ (fairly pronounced)	+++
Do heated as in Expt 1 ...	0	0	0	0
Do heated plus toluol	0	0	0	0
Filtered (paper) bacterial culture as in Expt. 1	+ (very slight)	+++	0	+ (fairly pronounced)
Do plus toluol ...	0	++	0	+ (very slight)
Do. heated as in Expt. 1	0	+	0	0
Do heated plus toluol	0	0	0	0

Various wool materials were incubated at 35° C. in corked test tubes with trypsin and similar ones in 300 cc. plugged flasks containing 50 cc. of buffered (*p*H 7·0) and non-buffered cultures of *B. mesentericus ruber.* In the bacterial series the materials were first neutralised and suspended with the lower ends dipping in the inoculated culture medium, viz. 50 cc.

of 3% nutrient broth solution. The addition of broth enhances the fibre-decomposing action of the organism. Inquiry led to the adoption of a *p*H 8·6 buffer for the trypsin solution which otherwise was as in Expt. 2. The wools were examined microscopically after appropriate periods.

Results—

Table III

Comparison of the Effects of Trypsin and Bacteria

The extent of fibre disintegration is expressed approximately in terms of an arbitrary scale of values, 0 to 10, where 0=no disintegration, 2=slight, 5=noticeable, 7=pronounced, and 10=very severe disintegration. The bracketed values represent the results for the buffered bacterial culture series.

Wool Material	0·25% Trypsin Solution								*B mesentericus ruber*					
	Hours								Days					
	1	2	4	7	24	48	96	168	1	2	3	4	7	10
1—70's Botany (tips removed), scoured in ether and warm water	0	0	0	0	1	5	7	?	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	1 (0)
2—60's Worsted cloth, scoured	0	1	2	4	8	9	9	9	0 (0)	0 (0)	2 (4)	3 (7)	6 (10)	7
3—Hosiery fabric, chlorinated and milled (heavily treated)	7	9	9	10	–	–			3 (4)	8 (8)	10 (10)	- –	- –	– –
4—Woven baby bag fabric, chlorinated	3	4	7	9	10	–	–	–	2 (3)	5 (6)	7 (7)	9 (9)	10 (10)	- –
5—60's Worsted cloth, scoured, treated with 2% pot bichrome, 1% H_2SO_4 and 10% Glauber's salt	0	0	0	0	1	3	5	6	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6—As No. 5 *plus* 3% Eulan N	0	0	0	0	1	2	2	3	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
7—As No 6 *minus* the pot. bichrome	0	0	1	2	4	5	7	7	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Apart from the time period, the similarity between the two methods is evident and it is therefore proposed to adopt the trypsin solution as the basis for a laboratory method for determining the resistance of wool and other animal hairs to bacterial action. The significance of the breakdown rates of the different wool materials will be discussed in a further paper dealing with natural and acquired resistance of animal fibres against bacterial action.

After prolonged exposure to trypsin only a small proportion of the isolated cortical cells appear to show signs of decomposition (Fig. 2). It is thus probable, as in the case of bacterial action (Bartsch[1], Gabriel[3]), that the proteolytic influence is confined chiefly to the substance which cements the elements together. The tryptic digestion method may hence be a more expeditious way of providing cellular material for study than the bacterial (Waters[7]).

A Suggested Technique for the Determination of the Resistance of Wool to Bacterial Action

(*a*) Trypsin solution	Trypsin (B.D.H.)	0·5 g.
	Water (dist.)	100 cc.
(*b*) Buffer solution (*p*H 8·6)[4] ...	0·10 M Potassium di-hydrogen phosphate	34 cc.
	0·05 M Borax	66 cc.

The wool (0·1 g.) is relieved of natural or added grease, wetted out in water and immersed in a mixture of 5 cc. each of solutions (*a*) and (*b*) in a test tube. Two drops of toluol are added and the tube corked and incubated at 35° to 40° C. Microscopical examinations of the wool are made first at hourly intervals and later after longer periods.

In view of the variations in resistance of animal fibres from different sources and the fact that the exact amount of fibre degradation cannot be estimated by simple means, a rigid standard of resistance for fibres in general cannot be adopted. A very rough approximation of disintegration may be made by carefully stretching groups of fibres, e.g. threads, etc. to breaking point by hand, but microscopical examination is required to give more accurate results.

Small portions of the wool are teased out in water and examined for evidence of fibre breakdown. The latter is initiated by a loosening of the epithelial scales, this being followed on the part of the fibre by the assumption of a striated appearance and increase opacity. The scales become detached either fragmentarily or conjointly in sheath-like masses and eventually the fusiform cortical cells separate, the fibre becoming thinner in the process. Teasing out of the material prior to examination increases this separation and hence serves to give a clearer impression of the extent of disintegration.

Most wools contain a proportion of fibres which have been severely damaged either by weathering or by chemical or other processing, and these are the first to break down under the influence of the trypsin. Experience enables discrimination to be made between these and the bulk of the fibres constituting the sample. Other fibres, possessing considerable inherent resistance, may show localised disintegration in the neighbourhood of some mechanical abrasion.

As a guide it is suggested that wool materials which show marked fibre disintegration after one hour's exposure to trypsin, (e.g. Nos. 3 and 4, Table III), possess very low resistance to bacterial attack. If after 6 or 7 hours' incubation only a few of the fibres show disintegration (Nos. 1, 5, 6, and 7, Table III), the sample has a very high resistance, while samples showing a similar condition after four hours (e.g. the scoured worsted cloth, No. 2, Table III) may be considered to be in normally good condition and to have an average resistance to bacterial action.

CONCLUSIONS

1—The disintegration of wool fibres into their component elements, epithelial scales and cortical cells, can be effected by exposure to an appropriately buffered aqueous solution of trypsin or pepsin.

2—The action of the trypsin solution is very similar to, but much more rapid than, that of proteolytic bacteria, and a technique is therefore suggested for determining rapidly the resistance of a sample of wool to bacterial attack.

3—Treatment with chrome or Eulan N, or both, increases the resistance of wool to bacteria. This phenomenon will be considered in a further paper dealing with the natural and acquired resistance of wool and other animal hairs to microbiological agencies.

ACKNOWLEDGMENT

Mr. J. Stott has ably assisted with this work.

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THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

19—THE RELATION BETWEEN THE STRENGTH, COUNT AND TWIST OF SINGLE WORSTED YARNS—PART I

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GENERAL CONSIDERATIONS

It is frequently necessary in carrying out experimental worsted spinning tests to compare the strength, elongation, and levelness of yarns which differ slightly in count and twist. If sufficient care is not taken to make some correction for these differences, any conclusions based on the relative strengths of the yarns may be quite misleading.

Over a small range of counts it has been found that the product strength × count (S.C.) introduces a sufficiently good correction for differences in count for most practical purposes, and this product is frequently quoted in reports of spinning tests. It is found, however, that this simple correction is only valid over a small range, the value of S.C. actually getting steadily smaller with increasing count. Moreover, this correction takes no account at all of any small differences in twist.

In a series of papers on "The Foundations of Yarn Strength and Yarn Extension",[1] Turner and others have developed the relation between the yarn properties of strength, count, and twist for cotton yarns by studying closely the relative effects of the fibre slippage and fibre breakage in the breaking of a yarn under stress. The results are summarised in the following extracts from Part II of that series of papers—

> "If tension is applied to drawn out roving emerging from the front rollers of a spinning machine, the material gradually pulls apart; very little tension is required to effect this, the material being only very slightly twisted. Here we have a pure case of fracture by slippage. Moreover, each pulled out end of the roving has a conical appearance, the length of the cone being about equal to the length of the fibre. The strength of the 'yarn' is determined by the frictional forces of fibre on fibre resisting the pulling apart. If now twist is applied to the drawn out end of the roving emerging from the front rollers of the spinning machine, torsional forces are brought into play, accompanied by compressive and contractive forces, *i.e.* the length of yarn is reduced in diameter and length, the extent of compression and contraction being dependent on the degree of twist. Owing to the action of the compressive forces the yarn will display greater resistance to tension, the total frictional force at any cross-section being increased. If the frictional forces are such that the force required to make the fibre slip at the place of yarn breakage is greater than the strength of the fibre at that place, then the yarn must suffer fracture.
>
> The Effect of Twist—We may now consider further the effects of differences in the twist of a yarn when the latter is subjected to an increasing tension. For the present we may confine our attention to a particular cross-section, remembering that it is the fibres which have their mid-points near this cross-section ('central' fibres) which bear a greater share of the load there, and that fibres at or near the axis of the yarn are much less likely to slip than those near the surface. As the tension in the yarn is increased, so the tension in all the fibres increases; the fibres at or near the surface may slip at an early stage, and so relieve

> themselves of the strain, causing a greater share of the load to fall upon the fibres near the axis, as the tension increases still more, so the stress is more and more concentrated on the axial fibres, and especially on the centred axial fibres at any given cross-section, until there comes a moment when one of the centred axial fibres may either slip or break. If one fibre slips or breaks, the equilibrium at the cross-section is upset, and other fibres may slip or break in rapid succession, leading to a complete fracture. Whether such a centred axial fibre actually slips or breaks depends on how the frictional force resisting motion compares with the strength of the fibre in tension.
>
> By increasing the twist at the given cross-section, we may greatly increase the resistance to the fibre slippage without causing much change in the strength of the fibre. With zero twist in the drawn out roving, breakage will be due to fibre slippage. As we increase the twist there will come a time when some of the centred fibres, especially those at the yarn axis, will break before they can slip. Further increase of twist will gradually extend the axial zone within which fibre fracture rather than fibre slippage occurs, so that the percentage of fractured fibres will increase with the twist Finally, in hard twisted yarns some of the fibres near the surface may also be sufficiently firmly gripped to break rather than slip; in such a case it is to be expected that a large percentage of the fibres of the cross-section will be fractured when the yarn breaks. With still harder twist there can be no accession of yarn strength through the prevention of fibre slippage, but a reduction may be caused by the high inclination of the fibres to the yarn axis and by the weakening effect of the torsion itself."

The main conclusion based on this theory and developed in the succeeding part of the paper is that the breaking of a cotton yarn is caused almost entirely by fibre rupture. This is not, however, necessarily the case with all types of textile yarns. The picture of the effect of twist on the breaking of a yarn is quite general, but in practice the physical properties of textile fibres are so markedly different that the relative parts played by fibre slippage and fibre breakage vary considerably.

For example, the lowest twist factor in normal use in the cotton industry is that for Egyptian weft which is usually quoted as 3·18 on the basis of cotton counts. Converting this to worsted counts (560 yards per lb.) the factor becomes 2·60, which is greater even than the normal value of 2.15 which is used for a hard twisted botany warp yarn. Other twist factors in normal use for single worsted yarns are as follows—

Hosiery	1·4
Soft worsted (botany weft)	1·65
Medium worsted (soft botany warp) ...	1·9
Hard worsted (botany warp)	2·15
Extra hard worsted	2·45

It is evident that normal worsted yarn twists are very much less than normal cotton yarn twists and the breaking of the yarn due more, therefore, to fibre slippage. The possibility of spinning worsted yarns with such low twists is due partly to the surface structure of the fibres and chiefly to the much greater fibre length.. Whereas the maximum length of a cotton fibre is about 5 cm., the fibre length in a 64's quality botany top will vary from 2 cm. to 16 cm. and in a 36's cross-bred quality from 4 cm. to 36 cm. Incidentally the relation between fibre length and fibre fineness is also different for cotton and wool. The coarsest wools are always the longest and in any given quality of wool, the shortest fibres are always the finest, the correlation between fibre length and fineness being quite high.

When comparing yarns of different counts it is usual to consider the appropriate twist in each case, and the generally accepted rule is that the ratio $\frac{T}{\sqrt{C}}$=constant. Actually it is found that slightly higher values of twist factor are necessary for the higher counts, but on the whole, this rule gives reasonable results in practice.

It is difficult to give an adequate theoretical explanation of this, but it can be shown that a constant ratio of T to $\sqrt{C}$ implies a constant longitudinal "angle of twist", and this has long been recognised as a basis for the comparison of yarns of different count. The fact that these two statements are only two separate ways of describing the same condition is not always made clear in the text books of the subject.

The simplest and most practical form of the relation between twist and yarn diameter is that used by Barker and Midgley,[2] namely—

$$\tan A = \pi TD \quad \text{(i)}$$

where A is the longitudinal angle of twist

T is the twist in turns per inch

D is the diameter of the yarn in inches.

The diameter of a yarn, however, is extremely difficult to define, and more difficult to measure. There is a generally accepted relation, however, which is used in weaving calculations, derived from the measurements of Ashenhurst, which for normal twisted single worsted yarns can be expressed in the simple form—

$$D = \frac{0{\cdot}047}{\sqrt{C}}$$

Combining this with equation (i) we have

$$\tan A = 0{\cdot}148 \frac{T}{\sqrt{C}} \quad \text{(ii)}$$

Thus for a constant angle of twist $\frac{T}{\sqrt{C}}$ = constant.

In the following table of commonly accepted relations between angle of twist and practical yarn experience, we have included the appropriate values of $\frac{T}{\sqrt{C}}$ derived from equation (ii) in each case.

Table I

Nature of Twist	Angle of Twist A°	Tan A	$\frac{T}{\sqrt{C}} = \frac{\tan A}{0{\cdot}148}$
Hosiery	12	0·213	1·44
Soft worsted	14	0·249	1·68
Medium worsted	16	0·287	1·94
Hard worsted	18	0·325	2·19
Extra hard	20	0·364	2·46
Twist for maximum strength ...	25	0·466	3·15
Special yarns	30–45	—	—

It is found in practice that for slack twisted yarns, slightly lower values than those indicated by this table are found to be satisfactory. This is due to the fact that the actual diameters in these cases are greater than those given by Ashenhurst's formula, and if the correct values could be substituted, lower values of $\frac{T}{\sqrt{C}}$ would be obtained.

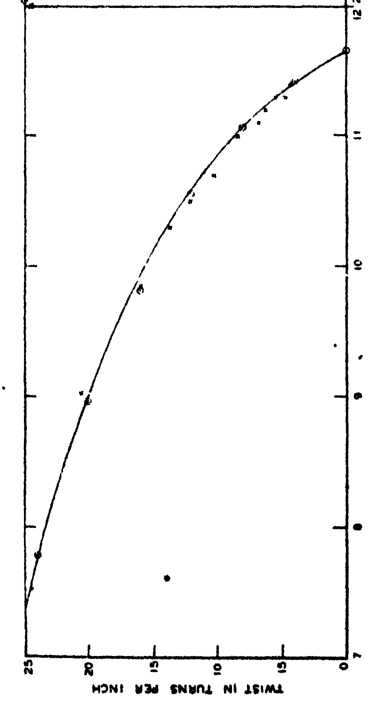

Fig. 1

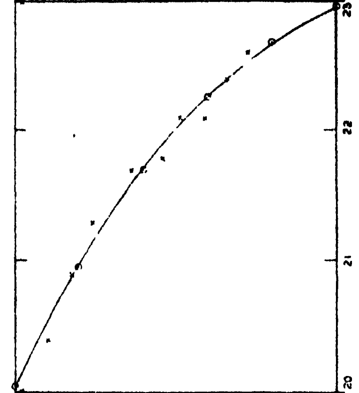

Fig. 2

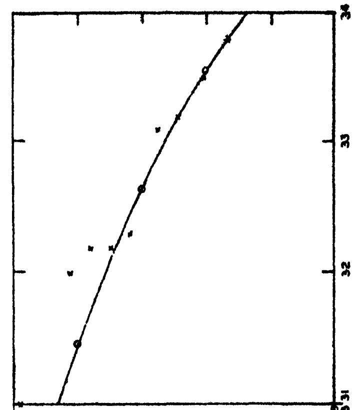

Fig. 3

EXPERIMENTAL

From rovings made from a good sample of 64's quality botany wool, a range of twists was spun on each of the following approximate counts—

1/11's, 1/22's, 1/33's, 1/46's,

the range in each case extending well above and below the ordinary range of twist factors. The spindle speed was kept constant at 5,550 r.p.m., and the twists were all measured by the stroboscopic method recently described in this *Journal*.[3]

From a knowledge of the weight of the roving and the draft in each case, the average number of fibres in the cross-section of the yarn could be calculated.

The yarns were afterwards conditioned for a week or more at 70% relative humidity, and from a knowledge of the regain of this particular wool under those conditions, the counts at standard condition in each case were calculated.

Details of the counts and twists in each case are given in Table II, and curves showing the take-up due to twist for three of the cases are given in Figs. 1, 2, and 3.

Table II

Measured Count at 18¼% Regain C.	Twist in Turns per inch T.	Twist Factor $k=\frac{T}{\sqrt{C}}$	Mean Count at $\frac{T}{\sqrt{C}}=2{\cdot}15$	Strength in ozs. S.	C. of V. of Strength V %	Elongation at Break E %	Value of S from Smooth Curve	Value of S calculated from Equation (iv)
9·86	15·9	5·06	11·1	17·2	9·6	—	17·2	17·2
10·3	13·7	4·27		17·6	7·9	29·3	17·4	17·1
10·5	12·1	3·73		17·1	8·3	26·7	17·1	16·8
10·7	10·2	3·12		15·9	9·1	22·2	16·0	16·2
11·0	8·47	2·55		14·6	7·5	18·8	14·6	15·0
11·1	6·75	2·03		12·5	7·9	14·7	12·4	12·8
11·2	6·13	1·83		11·2	8·7	11·6	11·2	11·6
11·3	5·31	1·58		9·8	9·7	10·3	9·3	9·6
11·3	4·74	1·41		7·3	17·7	10·2	7·3	7·7
11·4	4·23	1·25		4·9	24·7	9·6	4·9	5·5
20·4	22·4	4·95	22·3	7·1	16·9	17·7	7·1	7·0
20·9	20·5	4·48		7·3	15·9	17·9	7·2	7·1
21·3	19·0	4·12		7·2	17·0	16·7	7·2	7·2
21·7	15·9	3·41		7·1	13·5	14·8	7·1	7·0
21·8	13·7	2·93		6·8	13·4	15·1	6·8	6·8
22·1	12·1	2·57		6·2	11·2	13·6	6·5	6·4
22·1	10·2	2·17		5·9	11·5	11·4	5·8	5·7
22·4	8·47	1·79		4·9	11·8	9·2	4·8	4·6
22·6	6·75	1·42		3·2	24·6	6·8	3·0	2·8
31·0	24·5	4·38	33·3	4·00	21·1	11·0	4·05	4·05
31·6	22·4	3·97		4·10	21·1	11·5	4·10	4·10
32·0	20·5	3·62		4·15	18·7	11·1	4·10	4·15
32·2	19·0	3·34		4·05	16·6	11·1	4·10	4·10
32·2	17·3	3·05		4·00	17·8	10·0	4·05	4·05
32·3	15·9	2·79		4·00	17·9	10·2	3·95	3·95
33·1	13·7	2·38		3·70	16·4	9·5	3·70	3·60
33·2	12·1	2·09		3·55	14·5	8·8	3·40	3·25
33·5	10·2	1·76		2·85	20·0	7·0	2·80	2·60
33·8	8·47	1·46		1·80	28·8	4·5	1·80	1·60
43·7	24·5	3·70	45·9	2·55	24·9	8·1	2·60	2·60
43·6	23·4	3·54		2·60	21·8	8·5	2·60	2·60
44·2	22·4	3·35		2·40	21·8	7·5	2·60	2·60
43·7	21·4	3·24		2·55	22·8	8·4	2·60	2·60
44·8	19·8	2·95		2·65	18·1	8·1	2·55	2·55
44·2	19·0	2·85		2·55	20·0	8·1	2·55	2·55
46·7	17·3	2·53		2·35	19·2	7·9	2·45	2·45
45·7	15·9	2·35		2·30	19·6	7·5	2·30	2·30
45·8	14·7	2·18		2·15	20·9	6·9	2·15	2·15
46·7	13·7	2·00		2·00	20·2	6·1	2·00	2·00

The results for the 1/46's are too erratic to show any general tendency and those for the 1/33's are not very good, but in the other cases, where the yarns were spun from a heavier and probably more level roving, the points lie on definite curves of the type

$$C^2 = k_1 - k_2T - k_3T^2.$$

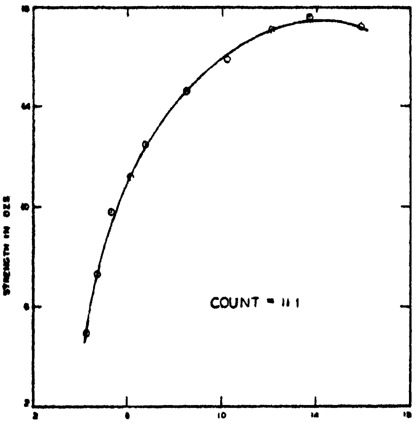

Fig. 4

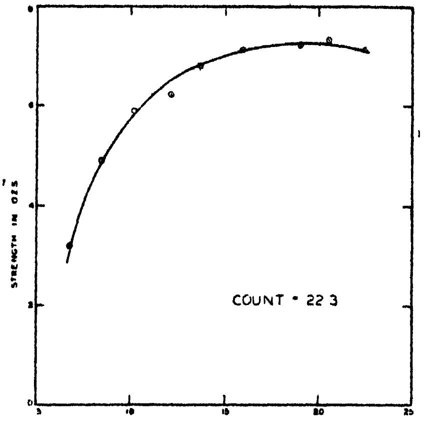

Fig 5

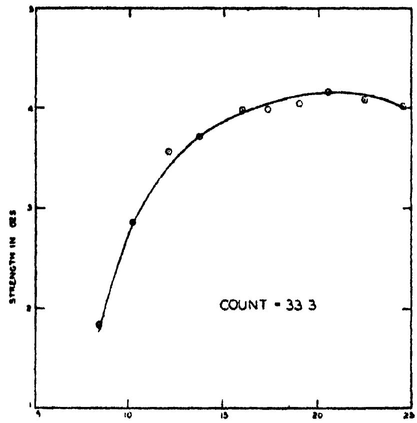

Fig. 6

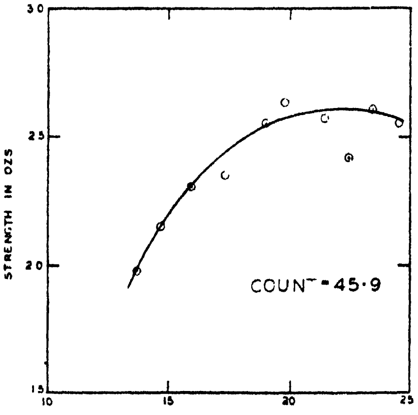

Fig. 7

The circled points are those calculated for the best smooth curve in each case. These curves were used to estimate the count at a value of the twist factor $\frac{T}{\sqrt{C}} = 2{\cdot}15$ in each group, and the value was used in the subsequent calculations, since it is of more value to the practical man than the number of fibres per cross-section.

The yarns were tested for strength and elongation on the Baer single thread tester using an 18 in. length and a stretching speed of 1 foot per min., 200 tests being made in each case. Care was taken to see that the count and strength measurements were made on the same yarn. The results of the yarn tests are included in Table II, and the figures showing the relation between strength and twist for each group are reproduced graphically in Figs. 4, 5, 6, and 7.

In each case it will be seen that the strength increases with twist up to a certain maximum value of twist in each case, beyond which point any further insertion of twist causes the strength to decrease. This maximum value is well above the ordinary working twists for worsted yarns varying from $\frac{T}{\sqrt{C}}=3{\cdot}35$ for 1/46's to $\frac{T}{\sqrt{C}}=4{\cdot}2$ for 1/11's. These values are higher than generally supposed. The change in the slope is due to change in the relative parts played by fibre slippage and fibre breakage in the breaking of a yarn, and by the weakening effect of the torsion at high twists.

Analysis of Results

Some idea of the form of the relation between S and T can be obtained by considering the shape of the experimental curves. It is quite reasonable to assume that each of these curves is a small part of some definite curve of known form, as long as the agreement between the two is sufficiently close over the range which is specified.

Let us assume for example that the ST curve is part of a general curve $S=f(T)$ which gives a definite value for $T=T_1$ when $S=0$, *i.e.* it cuts the T axis at some value of T_1 with a definite slope $\frac{dS}{dT_1}$. This is what would appear to be the case if we extrapolated the experimental curves downwards, although we know that actually in this region the curve will bend round a little and approach the T axis asymptotically.

As T is increased, S increases until the maximum strength S_m is reached, but the slope $\frac{dS}{dT}$ gradually diminishes, *i.e.* $\frac{d^2S}{dT^2}$ is negative. This condition is satisfied by an equation of the type

$$S = AT + \frac{B}{T}$$

where A and B are constants. Then we have

$$\frac{dS}{dT} = A - \frac{B}{T^2} = 0 \text{ when } T^2 = \frac{B}{A}$$

$$\frac{d^2S}{dT^2} = \frac{2B}{T^3}$$

which is only negative if B is negative. Thus for a real value of T for maximum strength A must also be negative.

These two terms alone would give a negative value of S for any given value of T, so that it is necessary to stipulate the presence of another positive term independent of T and numerically greater than $\left(AT + \frac{B}{T}\right)$.

An equation of the type

$$S = \alpha - \left(\beta T + \frac{\gamma}{T}\right) \quad \text{...} \quad \text{(iii)}$$

was therefore tried in each case and found to fit the ST curves very well over the range tested, but not for the very low twists for reasons already given, nor for twists beyond the maximum strength value, but these regions are of little practical value.

The fact that there is no appreciable strength until the twist reaches some definite value can be explained on the hypothesis of the radial closing up of the fibres; a certain definite twist is required to bring the fibres into any noticeable contact at all, and until this is effected no appreciable resistance to tension can be supplied by the friction of fibre on fibre. Another law altogether holds in this region. Once the fibres are in contact, however, a small increase in twist produces a large increase in strength owing to the increase of the radial compressional forces.

Equation (iii) gives a maximum value

$$S_m = \alpha - 2\sqrt{\beta\gamma} \text{ when } T^2 = \frac{\gamma}{\beta}$$

The most suitable values of the arbitrary constants α, β, and γ in each case were worked out in the following way. A preliminary trial showed the values of the constants α were almost exactly inversely proportional to the count, the mean value being given by $\alpha C = 330$.

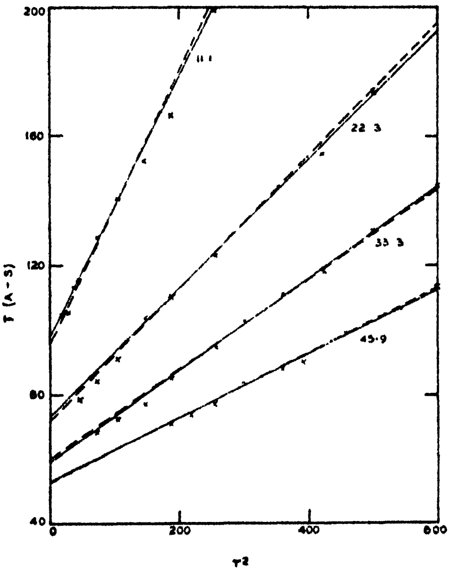

FIG. 8

In order to get the best two corresponding values of β and γ in each case, $T(\alpha - S)$ was plotted against T^2, since equation (iv) can be written in the form

$$(\alpha - S)T = \beta T^2 + \gamma$$

The best straight line through each set of points was calculated by Awberry's[4] method, and these are shown in Fig. 8. The calculated values of the constants are given in Table III.

Table III

C	α	γ	β	$C\alpha$	$\sqrt{C\gamma}$	$C\beta$
11·1	29·7	97·9	0·386	330	326	4·29
22·3	14·8	71·7	0·205	330	338	4·57
33·3	9·9	56·9	0·148	330	328	4·93
45·9	7·2	52·8	0·0996	330	357	4·57

It is obvious from the last three columns of Table III that there is some definite relation between the count C and the arbitrary constants β and γ in addition to that already found between C and α.

Seeing that the values of $C\beta$ show no general tendency in any one direction, and are of the same order, it can be assumed within the limits of experimental error, that β is inversely proportional to the count, the mean value being given by

$$\beta C = 4{\cdot}6.$$

The corresponding values of β in each case are 0·412, 0·206, 0·138, 0·100.

Using these values of β, *i.e.* the values of the slopes of the lines in Fig. 8 in conjunction with the "centre of gravity"* of the points in each case as a fixed value, the new corresponding values of γ were calculated, the results being as follows—95·5, 71·5, 60·0, 52·6.

The lines using these revised values of β and γ have been drawn in dotted on Fig. 8, and it will be seen that even in the case of the 1/11's and 1/33's which have required the most adjustment, the agreement with the experimental points is still close.

Finally in a last attempt to correlate the revised values of γ with the count, the values of $\sqrt{C}\gamma$ become 318, 337, 346, 357. These values are of the same order and as a first approximation we could take $\sqrt{C}\gamma=340$ as the mean value. Actually, however, there seems to be a small progressive increase of $\sqrt{C}\gamma$ with count, showing that γ is not quite inversely proportional to $\sqrt{C}$. It is found that if $\frac{1}{\gamma}$ is plotted against $\sqrt{C}$, the points lie accurately on the straight line.

$$\gamma = \frac{402}{\sqrt{C} + 0{\cdot}9}$$

The general equation therefore to fit all four groups of results is

$$S = \frac{330}{C} - \left(\frac{402}{T(\sqrt{C}+0{\cdot}9)} + \frac{4{\cdot}6T}{C}\right) \qquad \text{(iv)}$$

Values of S have been calculated from this equation for each value of T in each group and are given in the last column of Table II. Taking the approximate equation

$$S = \frac{330}{C} - \frac{340}{T\sqrt{C}} - \frac{4{\cdot}6T}{C} \qquad \text{(v)}$$

it will be seen that if we had plotted strength against twist factor, instead of the actual twist, *i.e.* substituting $\frac{T}{\sqrt{C}}=k$ we should have

$$S = \frac{330}{C} - \frac{340}{kC} - \frac{4{\cdot}6k}{\sqrt{C}} \qquad \text{(vi)}$$

This equation shows the gradual reduction in the value of SC with increasing count. One contributory reason for this is probably the fact that as the number of fibres in the cross-section of a yarn is increased, the number of "fibre contacts" increases much more in proportion. A photomicrograph of the cross-section of a worsted yarn reveals the fact that only about one-third of the total yarn area is occupied by fibres and there is no obvious inter-fibre contact at all. When the yarn is strained nearly to breaking point, however, the stresses even in the surface fibres will be sufficient to bring all the fibres into intimate contact with one another, and it is on the number of these contacts that the yarn strength to a great extent depends.

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* This is used in Awberry's method for calculating the best straight line.

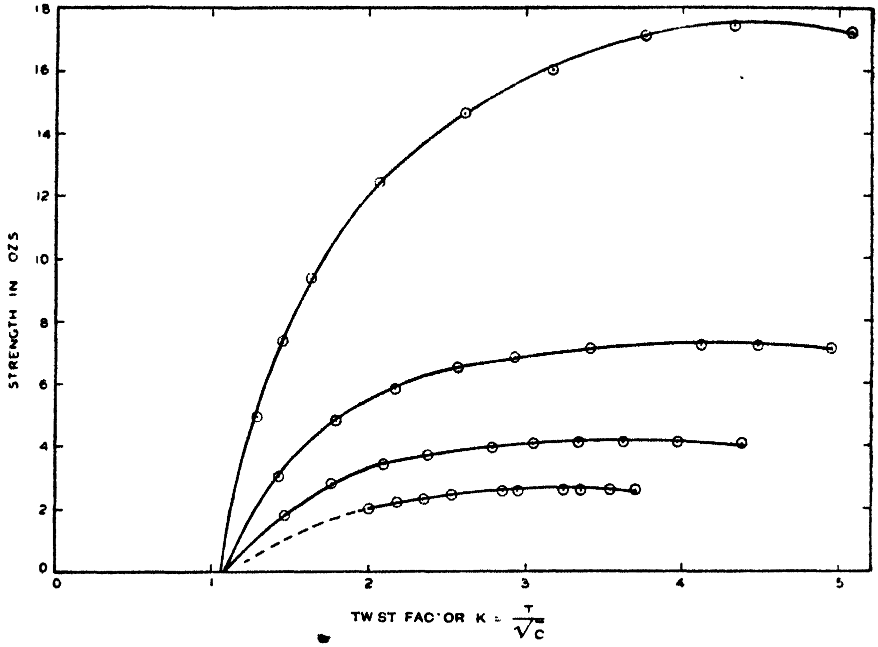

Fig. 9

If we put in equation (v) the condition that S=O and solve for T_1 we have

$$T_1 = \frac{\frac{330}{C} \pm \sqrt{\frac{330^2}{C^2} - \frac{4 \times 4{\cdot}6 \times 340}{C^{1{\cdot}5}}}}{\frac{2 \times 4{\cdot}6}{C}}$$

$$= 35{\cdot}9 \pm 35{\cdot}9\sqrt{1 - 0{\cdot}0575\sqrt{C}}$$

$$= 35{\cdot}9(1 - 1 + 0{\cdot}0288\sqrt{C}) \text{ approximately}$$

(taking the negative sign which gives the lower value of T_1)

i.e. $T = 1{\cdot}033\sqrt{C}$

This gives us the rather interesting result that whatever the count of the yarn, there must be a minimum twist factor $k = 1{\cdot}033$, to produce the necessary closing up of the fibres. This is shown in Fig. 9, where the strengths taken from the smoothed curves are plotted against twist factor k.

TESTS ON ANOTHER QUALITY

An interesting check on the suitability of this empirical type of relation between S, C, and T has been provided by its application to a set of measurements which were made on some 48/50's quality yarns about two years ago. For some other experiments a range of these yarns, varying in count from 1/16's to 1/28's were spun with three different values of twist for each count, and the single thread strengths were measured. The actual counts, as distinct from the nominal counts, were not measured at the time, but the ratios between all those in the set will be reasonably accurate since they were all drafted from the same roving.

The results are given in Table IV, and again in the last column values of the strength S are given calculated from the equation

$$S = \frac{390}{C} - \frac{417}{T\sqrt{C}} - \frac{6{\cdot}6T}{C}$$

or $$S = \frac{390}{C} - \frac{417}{kC} - \frac{6{\cdot}6k}{\sqrt{C}} \qquad \text{..(vii)}$$

where *k* is the twist factor. The constants here are different as the wool is different, but the general form of relation between S, C, and T is the same.

It will be seen that the maximum disagreement between the calculated and measured values is 5% and the average disagreement about 2%, which is about the same as the order of accuracy of the experimental measurements.

Table IV

Nominal Count C	Twist in turns/inch T	Twist factor $\frac{T}{\sqrt{C}}$	Single thread strength in ozs S	Value of S calculated from equation (vii)
16	6·97	1·74	6·4	6·5
	7·58	1·90	7·7	7·5
	8·13	2·03	8·3	8·2
18	7·58	1·79	5·8	5·9
	8·13	1·92	6·4	6·6
	8·98	2·12	7·5	7·4
20	8·13	1·82	5·2	5·3
	8·98	2·01	6·3	6·1
	9·75	2·18	6·8	6·7
22	8·98	1·92	5·1	5·1
	9·75	2·08	5·5	5·7
	10·33	2·20	6·3	6·0
24	9·75	1·99	4·9	4·8
	10·33	2·11	5·0	5·1
	11·00	2·25	5·5	5·5
26	10·33	2·03	4·3	4·5
	11·00	2·16	5·0	4·8
	11·76	2·31	5·2	5·1
28	11·00	2·08	4·0	4·2
	11·76	2·22	4·3	4·5
	12·63	2·39	4·6	4·7

USE OF THE GENERAL EMPIRICAL S.C.T. RELATION

The general relation (iv) will be valuable in analysing the significance of comparative yarn strength tests. For example, where it is desired to investigate the effect on yarn strength of some different method of treatment during processing, it is often extremely difficult to spin the final yarns which are to be compared to exactly the same count and twist, and unless due allowance is made for this, a comparison of the yarn strengths may be misleading. By a suitable use of equation (iv), however, the necessary corrections can be applied.

Taking the simplified equation (vi), *i.e.*

$$S = \frac{330}{C} - \frac{340}{kC} - \frac{4{\cdot}6k}{\sqrt{C}}$$

there are a number of methods of variation which can be considered.

(1) Variation of twist angle A or twist factor k keeping the count constant.

$$\left(\frac{dS}{dk}\right)\text{C const.} = \frac{340}{k^2C} - \frac{4{\cdot}6}{\sqrt{C}}$$

$$\textit{i.e.}\quad dS = \frac{dk}{C}\left(\frac{340}{k^2} - 4{\cdot}6\sqrt{C}\right)$$

Thus in a 1/36's yarn, a change in k from 1·9 to 2·1 (mean 2.0) will produce a change in strength

$$dS = \frac{0{\cdot}2}{36}(85 - 27{\cdot}6)$$

$$= 0{\cdot}32 \text{ ozs.}$$

the actual strength at k=1·9 being 2·76 ozs.

(2) Variation of count keeping the twist factor constant

$$\left(\frac{dS}{dC}\right)k\text{ const.} = -\frac{330}{C^2} + \frac{340}{kC^2} + \frac{4{\cdot}6k}{2C^{\frac{3}{2}}}$$

$$\textit{i.e.}\quad dS = \frac{dC}{C^2}\left(-330 + \frac{340}{k} + 2{\cdot}3k\sqrt{C}\right) \qquad \text{......................(viii)}$$

Thus again, taking a 1/36's yarn with a twist factor k=2, unit change in count will produce a change, in strength

$$dS = \frac{1}{1296}(-330 + 170 + 27{\cdot}6)$$

$$= -\frac{132{\cdot}4}{1296} = -0{\cdot}102 \text{ ozs.}$$

the minus sign indicating a drop in strength with increasing count.

The actual strength is S=2·92 ozs.

Now if we had used the usual strength × count product correction we should have had

$$SC = 2{\cdot}92 \times 36$$

$$= 105$$

$$\text{and } dS = -\frac{105}{C^2}dC$$

$$= -0{\cdot}081 \text{ ozs. when } dC = 1.$$

The difference between this value and the correct value 0·102 ozs. is small and under these circumstances (*i.e.* constant twist factor) the strength × count product correction would be sufficiently accurate for most purposes, especially for low counts where the third term, $2{\cdot}3k\sqrt{C}$ in equation (viii) becomes of less and less importance.

Actually in practice, the strength × count product correction is often applied to conditions which may produce a much greater error, as will be seen from a consideration of the third class of variation.

(3) Variation of count keeping the twist constant.

This is the case most often met with in practice, the ratio between the front roller and spindle speeds remaining constant, and the count varying slightly due to irregularities in the roving. Reverting back to equation (v) and differentiating, we have

$$\frac{dS}{dC} = -\frac{330}{C^2} + \frac{340}{2TC^{\frac{3}{2}}} + \frac{4{\cdot}6T}{C^2}$$

$$i.e.\quad dS = \frac{dC}{C^2}\left(-330 + 4{\cdot}6T + \frac{170\sqrt{C}}{T}\right)$$

Again taking the case of a 1/36's yarn, $k=2$, *i.e.* $T=12$, we have for unit change in count

$$dS = \frac{1}{1296}(-330 + 55 + 85)$$

$$= -\frac{190}{1296} = -0{\cdot}146 \text{ ozs.}$$

which is nearly twice as great as that which would have been given using the simple straightforward strength × count product correction. The percentage error is

$$\left(\frac{0{\cdot}146 - 0{\cdot}081}{2{\cdot}92}\right)100 = 2{\cdot}2\%$$

This perhaps may be made clearer by considering two yarns, spun with the same twist, having strengths and counts, SC and S′C′, respectively. We have

$$SC = (330 - 4{\cdot}6T) - \frac{340}{T}\sqrt{C}$$

$$S'C' = (330 - 4{\cdot}6T) - \frac{340}{T}\sqrt{C'}$$

again taking $C = 36$, $C' = 37$, and $T = 12$ we have

$$\frac{SC}{S'C'} = \frac{9{\cdot}69 - \sqrt{C}}{9{\cdot}69 - \sqrt{C'}} = \frac{3{\cdot}69}{3{\cdot}61} = 1{\cdot}022$$

$$i.e.\quad SC = 1{\cdot}022\, S'C'$$

showing that an error of 2·2% would have been made if we had taken $SC = S'C'$.

The error will vary with count and twist so that it is necessary to work out the correction to be applied in every individual case in order that reliable comparisons can be secured.

The practical significance of this discussion will be evident from the following example. Supposing the following two results had been obtained from yarns which had been spun with the same draft and twist on the same frame, but under some different conditions of roller settings.

Yarn	Count	Strength	Count × Strength
A	36	2·92	105
B	34	3·22	109·5

B would have been classed as slightly superior to A, although the difference is not greatly significant. Actually, however, the strength of yarn B, corrected to 36's count is exactly 2·92, so that no effect at all can be attributed to the difference in roller settings, the count × strength product being quite misleading.

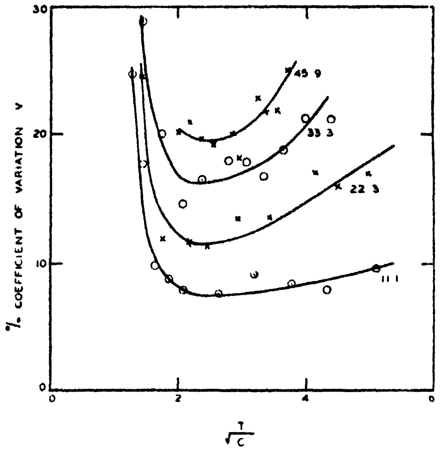

FIG. 10

YARN REGULARITY IN RELATION TO TWIST AND COUNT

Referring back to Table II, a study of the relation between the twist factor k and the coefficient of variation V of the strength tests, is of interest.

At the extreme ends of the twist range in each set, the value of V is very high. Actually it is found that if V is plotted against k as in Fig. 10, the smoothed curve in each case has a minimum at a value of k about 2·3 to 2·5. Further, the minimum values V_m of V in each case bear a direct relation to the count given by $V_m = \frac{C}{3} + 3{\cdot}8$. This relation, moreover, appears to hold approximately over the whole of the twist factor range so that when $\frac{V - 3{\cdot}8}{3}$ is plotted against k, all the points for all four sets lie about one curve which has a minimum value at $k = 2{\cdot}37$. The curve is not symmetrical but increases very steeply as the twist factor is reduced below 2·0. This is due to the fact that below a certain twist, the compressional forces are insufficient to bring the fibres into appreciable contact at all and it becomes impossible to spin the yarn, and as this condition is approached the yarn becomes very uneven.

Purely from a point of view of mathematical interest, the shape of the combined curve suggested that if $\frac{V - 3{\cdot}8}{C}$ was plotted against $\frac{1}{k}$ instead of k, a symmetrical curve would result. This was found to be the case, the points lying over a fairly wide range on the parabola

$$\frac{V - 3{\cdot}8}{C} = 4{\cdot}85\left(\frac{1}{k}\right)^2 - 4{\cdot}09\left(\frac{1}{k}\right) + 1{\cdot}21$$

which has a minimum at $\frac{1}{k} = 0{\cdot}422$ or $k = 2{\cdot}37$.

The same type of relation holds for the 48/50's crossbred yarns, the minimum value of V being at about the same value of *k*, which obviously seems to be about the most suitable value as far as yarn regularity alone is concerned.

YARN EXTENSION IN RELATION TO TWIST AND COUNT

A consideration of the figures for elongation at break in Table II, is of interest. In Table V, the ratio of the extension to the strength (values taken from the smoothed curve) is given for each value of the twist factor *k*, and the relation between these is shown in graphical form in Fig. 11. Although the points are rather irregular the smoothed curves do show certain definite tendencies which admit of a tentative explanation.

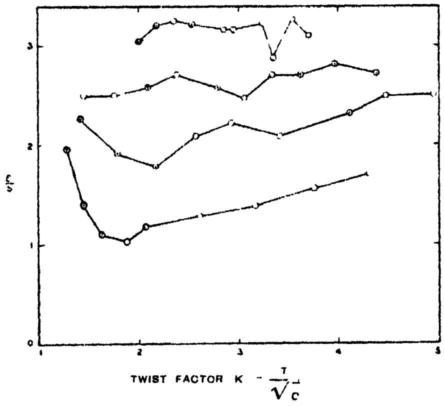

FIG. 11

Let us consider first of all a very slack twisted yarn which is being subjected to increasing tension. The air spaces between the fibres making up the yarn are initially quite pronounced and the first effect of the tension is to bring the fibres into closer contact, with a corresponding increase in the length of the yarn. The tension required to bring the fibres into contact is not very great as there is very little frictional force to overcome, but the extension produced is quite large in proportion. This effect will be greater for the heavier yarns owing to the greater number of fibres which have to be brought into contact before frictional forces become operative. If the initial twist is very small, fracture of the yarn may take place while the frictional forces between adjacent fibres are still very small and in this case the ratio of E to S will be quite large. This state of things is shown up quite clearly by the shape of the initial part of the curves in Fig. 11. As the initial twist is increased, however, that part of the extension due to the closing together of the fibres becomes of less and less importance with a corresponding reduction in the ratio $\frac{E}{S}$. Resistance to extension is now caused by inter-fibre friction until the tension increases sufficiently to cause fibre slippage.

As the twist factor is further increased, the extension seems to be more or less proportional to the breaking strength, the extra binding effect due to the twist compensating for the smaller number of fibres in the cross-section at the breaking point due to the greater extension.

As the initial twist factor is still further increased, a point is reached as we have seen when the inter-fibre frictional forces are great enough to prevent drafting and yarn extension then is due mainly to the actual extension of the fibres themselves. The extension of a wool fibre (near its breaking point) increases much more than in proportion to the load, so in consequence the ratio $\frac{E}{S}$ will once again tend to increase. This is shown up quite clearly in the curves.

It will be seen from Fig. 11 that the region over which the ratio $\frac{E}{S}$ is approximately constant, extends from $k=1{\cdot}6$ to $k=2{\cdot}4$, and this is the range normally used in practice.

Table V

C=11·1		C=22·3		C=33·3		C=45·9	
Twist Factor	Ratio $\frac{E}{S}$	Twist Factor	Ratio $\frac{E}{S}$	Twist Factor	Ratio $\frac{E}{S}$	Twist Factor	Ratio $\frac{E}{S}$
4·31	1·70	4·95	2·50	4·38	2·72	3·70	3·11
3·76	1·56	4·48	2·49	3·97	2·81	3·54	3·27
3·17	1·39	4·12	2·32	3·62	2·71	3·35	2·88
2·61	1·29	3·41	2·09	3·34	2·71	3·24	3·23
2·07	1·19	2·93	2·22	3·05	2·47	2·95	3·17
1·88	1·04	2·57	2·09	2·79	2·58	2·85	3·17
1·63	1·11	2·17	1·79	2·38	2·71	2·53	3·22
1·45	1·40	1·79	1·92	2·09	2·59	2·35	3·26
1·29	1·96	1·42	2·27	1·76	2·50	2·18	3·21
—	—	—	—	1·46	2·50	2·00	3·05

ACKNOWLEDGMENT

Mr. J. R. Ickringill has carried out the spinning involved in the above work, and has also assisted considerably in the analysis of the results.

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20—ABSORPTION OF WATER BY LINEN

PART I—FLAX YARNS

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INTRODUCTION AND SUMMARY

There are singularly few records of exact measurements on the absorbency of flax yarns and fabrics, although it is undoubtedly a property of very great importance to the ultimate users of a number of different fabrics. This paper is intended as a record of measurements of the absorbency of flax yarns. This was regarded as a necessary preliminary to measurements of absorbency of fabrics. Whilst the latter is what actually concerns the user, yet it is necessary to know the relation between the properties of the yarn and the fabric, in order to be able to draw definite conclusions as to the relations between the properties and structure of the fabric.

"Absorbency" is a term very commonly used in connection with textiles, particularly towels and underclothing materials. To speak of the absorbency of a cloth, is, however, rather indefinite. The behaviour of the cloth with respect to the water depends on two factors: (1) the rate of wetting of the surface of the fibres, (2) the total amount of water which can be held in the cloth. For cloths for certain special purposes, one of these may be of much greater importance than the other. The term absorbency is very often used to mean either of these factors, but in order to be quite explicit, they will be considered in this and succeeding papers as distinct properties, and will be referred to as "rate of wetting" and "per cent. water held", respectively.

A method of measuring the absorbency of yarns is described and the necessary precautions to ensure reliable comparisons of samples are deduced from the results obtained by varying the experimental conditions. The chief features of the method are that it enables separate measurements of the two aspects of absorbency, namely the completeness of wetting after a fixed time of immersion and the amount of water held, and it is equally applicable to yarn or fabric. Several other types of absorbency tests have been used by various workers, which no doubt have considerable interest for particular purposes. The results given by this method reveal clearly how the absorbency varies with variation of conditions, type of yarn, chemical treatment, or yarn construction. The importance of considering absorbency as of two distinct kinds is emphasised by the experimental results, as it is found that in some circumstances the completeness of wetting and the per cent. water held do not always vary similarly.

The main conclusions relating to factors which affect the absorbency of yarn deduced from the present experiments are briefly summarised as follows—

(1) The completeness of wetting (expressed as per cent. of fibre surface wetted or apparent density in water of the partly wetted fibre in the yarn) increases rapidly with time of immersion, reaching within a very short time a value which then remains approximately constant over some decided range of time. This maximum value is attained more rapidly and approaches nearer to complete wetting with increase of temperature of the water.

(2) With wet spun yarns and water at 20° C., the completeness of wetting is increased progressively by boiling and by successive stages of bleaching. With dry spun yarns the increase on boiling is most pronounced and is followed by a gradual increase on bleaching.

(3) Under given conditions the per cent. water held by wet spun yarn increases on boiling and bleaching, but with dry spun yarn the grey yarn holds more water than the boiled and bleached.

(4) The variation of per cent. water held with change of temperature is peculiar. In all cases with boiled and bleached yarns the water held decreases with increase of temperature, but with grey yarns an increase is shown.

(5) Dry spun yarn holds more water than wet spun yarn, and in wet spun, tow yarns hold more water than line of the same count. There is in fact an inverse relationship between the compactness of the yarn and the per cent. water held; the latter also depends on the completeness of wetting.

(6) In grey and boiled wet spun line yarn, the chief effect of variation of lea is an increase in the per cent. water held with increasing count. This appears to be due to variation in amount of water held on the surface.

(7) The ease of wetting grey line wet spun yarns of equal count spun from different kinds of flax show very considerable differences, especially in cold water. The per cent. water held also varies and not altogether in the same manner as the completeness of wetting. These effects are attributed to differences in compactness and condition of the yarn surface.

(8) At low temperatures the ease of wetting increases with increasing twist in the yarn. The effect is most pronounced in grey yarn and decreases on boiling and bleaching. Dry spun yarns show more variation with twist than wet spun yarns. In grey yarns the per cent. water held rises to a maximum and then decreases with increasing twist, but in boiled and bleached yarns the per cent. water held decreases from a lower twist.

EXPERIMENTAL METHOD

During the last few years much consideration has been given by various workers to methods of testing wetting-out agents. This is the converse of the problem in hand, as they have a standard specimen of material and vary the liquid. In one of the most commonly adopted methods[1] a specimen of cloth, attached to a sinker, is placed on the liquid, and the time to sink is noted; some use short bundles[2] or small coils of yarn. Another method[3] is to attach the cloth and sinker to a spring or the arm of a balance and determine the time to come to constant weight. Another test used[4] is to determine the time for a definite volume of solution to wet out and flow through a piece of standard cloth. Methods used for testing absorbency of textiles generally relate to cloth and several tests have been proposed. One method is to measure the height of rise of liquid in a strip of cloth suspended vertically with the lower end in the liquid. Another is the drop test, in which the time is taken for a drop to be absorbed and the diameter of the spread is measured. Another test is to measure the amount of water absorbed when placed in contact with a wet surface.

None of these methods appeared to be suitable for our purpose. It was considered desirable that the method should be (1) equally applicable to yarn or fabric; (2) permit determination of the rate of wetting; (3) permit determination of the amount of water held. The first condition almost inevitably disposes of methods involving the submersion of bundles or coils of yarn; the condition of packing would have a very great effect on the result and it would be impossible to ensure constancy in this respect when comparing different sizes and kinds of yarn. Similarly the drop and height of rise tests are eliminated as these also require to be carried out on bundles of yarn in order to obtain a sufficiently marked effect.

It was finally decided to draw a quantity of yarn or strip of fabric through the water, and weigh before and after. This gives the amount of water held by the material due to the treatment. The estimation of the degree of wetting effected is made by determining the apparent density of the material in water after treatment, from which it is possible to calculate the completeness of wetting, knowing the absolute density of the fibre and the apparent density of the dry material, as explained later. By carrying out separate tests with varying times of immersion, the rate of wetting can then be determined.

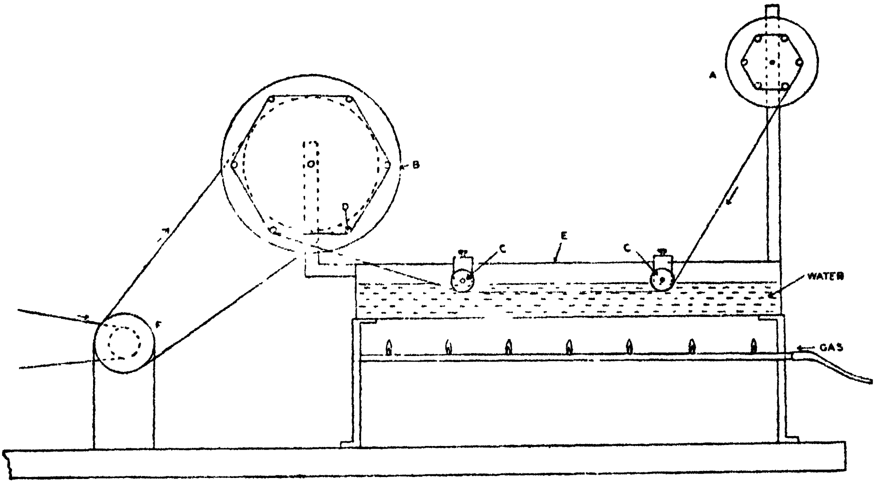


Fig. 1

The apparatus shown diagrammatically in Fig. 1 was constructed to enable the necessary experimental conditions to be obtained. As we are unaware of previous work using this method, some preliminary work was done to test out the reliability of the method, and to determine the best experimental conditions for routine comparison work. The trough E, 26 in. long, 4½ in. wide, 3 in. deep, heated from below by gas burners to maintain any desired temperature, supports two freely rotatable rollers C, the distance apart being adjustable. At one end of the trough, an upright support carries a fixed spindle overhanging the trough. On this spindle a wood barrel A, fitted with brass bushes, revolves freely or could be braked by fitting a spring to bear on one side of the barrel. At the other end of the trough a wood disc B, carrying six brass pegs, overhangs the trough. This acts as a take-up pulley, and by removing one brass peg the coil of material wound on is slackened and can be quickly removed over the ends of the pegs with very little handling. The disc B is driven by a motor through two similar stepped pulleys at F and on the back of B, enabling a wide range of speeds, with a fine adjustment by means of a resistance in series with the motor. Lengths of fine cord are fixed permanently to A and B, each having a small hook at the free end. By means of these cords and hooks the whole length of any sample can be run through the water under the same conditions; also by engaging the hooks with each other the cords can be run from one barrel to the other and direct determinations made of the time of immersion, by timing the passage of the hooks from entry to exit from the water surface. Preferably the exit position of the sample should be fixed, and the position of entry varied.

To carry out a measurement, the sample of yarn is prepared in the following way. The yarn is unreeled from a swift and carried backwards and forwards over two pegs placed 15 feet apart, until there are enough strands to weigh about 1·5 grams. These are then cut at the pegs, the ends knotted together and coiled up to permit weighing on a chemical balance. One end of the specimen is hooked on to the cord fixed to barrel A, and the whole wound on; the cord from barrel B is taken beneath the rollers C and the end hooked on to the yarn specimen at A. The temperature of the water in the trough and the speed of the take-up barrel B having been previously adjusted to the required conditions, the motor is started and the yarn transferred from barrel A to B, passing through the water in transit. When all the yarn is wound on to B the motor is stopped, the hooks disconnected, the detachable rod removed, the coil of wetted yarn removed from the take-up barrel, placed in a glass vessel with cover and weighed. The difference between the final and original weight gives the weight of water picked up, which is expressed as a percentage of the original air dry weight of the yarn (per cent. water held).

The glass vessel used is a Grace's Volumeter, a cylindrical glass vessel of about 50 c.c. capacity with a wide rim ground flat, and supplied with a light flat disc which is held in position merely by a trace of vaseline round the edge. To determine the completeness of wetting the volumeter is filled with water at 15° C. and the coil of wetted yarn gradually immersed with slight shaking to disengage air from between the laps, but not squeezed so as to disengage any air still present in the interior of the yarns. When completely immersed, the bottle is filled up with water, the cover slid into position to seal the vessel without inclusion of air bubbles, the exterior dried with a fine dry linen cloth and weighed.

If W_0 = weight in grams of glass vessel empty
W_1 = ,, ,, ,, filled with water at 15° C.
W_2 = ,, ,, ,, plus yarn filled with water at 15° C.

w = original air dry weight of yarn in grams
d = apparent density of partly wetted yarn

$$\frac{w}{V} = \frac{w}{W_1 + w - W_2}$$

If after immersion of the yarn in the volumeter, it is pressed with a glass rod until all air is completely removed, then

W_3 = weight of glass vessel + yarn + water at 15° C.
d_0 = absolute density of fibre in yarn

$$W_1 + w - W_3$$

If after the immersion in the trough $d=d_0$, then it is known that the sample has been completely wetted, but if incompletely wetted, "d" will be less than "d_0". The percentage of fibre surface wetted can be calculated as follows—

Let d_s=apparent density of the dry yarn, determined by the oiling and water immersion method previously described.[5] Then in the dry yarn, per cent air content $= \frac{d_0 - d_s}{d_0} \cdot 100$, and in partly wet yarn per cent. air content $= \frac{d_0 - d}{d_0} \cdot 100$. Assuming that the amount of unwetted fibre surface is proportional to the air content of the yarn,

$$\therefore \text{ per cent. wetness} = \frac{\text{dry fibre} - \text{unwetted fibre}}{\text{dry fibre}} \cdot 100$$

$$= \frac{(d_0 - d_s) - (d_0 - d)}{(d_0 - d_s)} \cdot 100$$

$$= \frac{d - d_s}{d_0 - d_s} \cdot 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is unnecessary to use this formula when comparing the effect of changes of immersion conditions on any one sample of yarn, but when different yarns are used having different values of d_0 and d_s, then it would be necessary to use the formula.

INVESTIGATION OF THE METHOD

The conditions in the experiment described above must exist in any commercial process for the wet treatment of yarn and so the test is representative of practical conditions. They are not those of a simple immersion, since there are also the associated effects of pressure at the rollers and on the rods of the take-up barrel, of tensions, of velocity, of the use of several parallel strands, and of the time the material is out of water before completing the density measurement. Some investigation was considered desirable, to determine the extent to which they might affect the measurements. The accuracy of the measurement should not be in question, as the conditions are all controllable, but the interpretation of the results might be affected.

EFFECT OF TIME FACTOR

The time of immersion depends on the velocity of the yarn and the distance between the rollers C. Within a limited range, varying times of immersion could be obtained with a constant yarn speed by varying the distance. Outside this range of times, it would be necessary to alter both the speed and the distance. Similarly a constant time of immersion could be attained by various combinations of speed and distance. The effect of variation of velocity involves the introduction of a variable time factor, even when the actual time of immersion in the water is constant, as this affects the time the first part of the specimen is out of water before the last part is clear. A similar time factor effect is introduced if different length specimens are used for comparison. The possible effect of this time factor was tested as follows—

A number of samples of the same yarn were prepared containing the same number of strands, but of lengths 20, 15, 10, and 5 feet. These were tested under the same conditions to give a time of immersion of 2 seconds, so that the time out of water would decrease with the shorter lengths.

The results are shown in Table I, and it is clear that there is no evidence that the longer length samples are more completely wetted owing to part of the sample being out of the water longer than in the shorter length samples.

Table I

3 lb. D.S. line yarn. 4 Strands. 2 Seconds immersion, water at 17° C.

Length of Sample feet	Apparent Density			Per cent. Water Held		
	Grey	Boiled	Bleached	Grey	Boiled	Bleached
20	1·12	1·14	1·36	176	161	248
15	1·16	1·16	1·36	157	177	242
10	1·15	1·13	1·37	155	184	248
5	1·14	1·14	1·39	166	174	269

In another experiment the yarn was immersed in water at 17° C. for 2 seconds, but four different lengths of path in the trough were used, so permitting the use of a 4:1 range of speeds. The results of these measurements are shown in Table II; they are in very fair agreement and show no consistent change with variations in yarn speed.

Table II

3 lb. D.S. line yarn. 4 Strands 15 ft. long.
2 Seconds immersion, water at 17° C.

Distance between rollers, inches	Speed	Apparent Density		Per cent Water Held	
		Grey	Boiled	Grey	Boiled
16	1	1·22	1·15	176	177
12	1·3	1·19	1·15	177	186
8	2	1·18	1·18	184	181
4	4	1·18	1·19	170	204

The figures in Tables I and II show that measurements of completeness of wetting can be repeated very closely. Greater variation is liable in the repeat measurements of the amount of water held, but even so the variation is not excessive. These measurements show that the result depends on the time of immersion in the water and are unaffected within fairly wide limits by variations in yarn speed or time between exit from the water and completion of the measurement.

The Effect of Pressure on the yarn at various parts of the apparatus was examined by testing yarns with 1 sec. immersion in the apparatus, in the way described, and by holding a coil of the same yarn below water for the same time. The results are shown in Table III.

Table III

Yarn—2 lb. D.S. super warp line. 1 Second immersion at 17° C.

Yarn	Apparent Density	
	Run through Apparatus	Coil under Water
Grey	1·20	1·13
Boiled	1·25	1·13
Bleached ...	1·44	1·41

In each case the yarn run through the apparatus was more completely wetted than that simply immersed. This is attributed to the slight but definite pressure on bending at the rollers and on the rods during winding. It is more noticeable on the less easily wetted grey and boiled yarns. As the method is chiefly for comparative measurements, this is not important but reveals the necessity for strict control of the extent of bending round the rollers, i.e., the yarn path should be constant.

The Effect of Tension was examined by testing a sample of grey yarn, with and without tension, using a series of times of immersion. The results are shown in Table IV.

Table IV

Yarn—2 lb. D.S. super warp line, grey. Immersed at 15° C.

Time of Immersion Seconds	Apparent Density	
	Without Tension	With Tension
0·2	—	1·13
0·45	1·18	1·18
1·9	1·19	1·19
2·1	1·24	—
2·4	—	1·19
3·5	1·09	—
4·6	1·18	—
5·9	—	1·19
11·8	1·20	—
17·4	—	1·29
19·0	1·24	—
51·0	—	1·29

With tension, the results form a very consistent series with increasing time; after a sharp rise the apparent density remains constant for about 10 seconds, then rises and remains constant over a further 30 seconds. Without tension, the results were not so consistent, as two erratic results were obtained, but for the shorter times the apparent density was the same whether tension was or was not applied. It was concluded that it was advisable to use a fixed tension for yarn tests, as greater regularity of conditions could be obtained; the tension used was not large, just enough to prevent over-running of the supply bobbin.

With a loose fibrous structure such as rove, the conditions are very different, and the result is very sensitive to changes in tension. Some results for rove are shown, as a matter of interest, in Table V.

Table V

Rove. Courtrai tipples. 240 yards per ounce. Immersed at 40° C.

Time of Immersion Seconds	Apparent Density	
	Without Tension	With Tension
0·4	0·77	0·94
6·0	0·63	0·98
15·2	0·81	1·06
20·4	0·84	—
22·8	—	1·39
27·0	1·09	1·45

The difference in the values is much more pronounced, and the tension considerably affects the rate of wetting for all times of immersion. Hence in testing such materials as rove, the importance of constant tension is very great. Application of tension causes more intimate contact between the fibres and apparently this leads to acceleration in wetting. This is borne out because in forming yarn, high twist is inserted which also brings the fibres closer together, and the results in Tables IV and V, without tension, show that for a given time of immersion in cold water grey yarn is very much more completely wetted than rove.

The Effect of Number of Strands was investigated. In order to secure accuracy in the apparent density measurement, it was necessary to have a sample weighing about 1·5 grams. The most definite way would be to run the necessary length through as a single thread, but it was considered desirable that the time of exposure of the partly wetted yarn after leaving the trough should be reduced to the minimum, to lessen effects of evaporation or an increase of wetting. This can be reduced to a very short time by using many strands of short length. In order to determine the possible effects of these alternative experimental conditions, tests were made with varying numbers of equal length strands. In one case the strands were allowed to remain in contact whilst passing through the water, in the other case the strands were kept separate whilst in the water by means of a grid fixed in front of the first roller. The completeness of wetting on leaving the water was the same in all cases, but the values for the per cent, water held, varied considerably as shown in Table VI. When the strands were separated whilst under water, the result for per cent. water held was fairly independent of the number of strands. When the strands were allowed to remain in contact whilst under water, the value for per cent. water held was much higher than for separate strands, and moreover, it increased regularly with increasing number of strands. The first value is really the amount of water held in and on the yarn, whilst the higher values are due to water held by the bunch of yarn in the spaces between the yarns. It is evident, therefore, that attention must be paid to the experimental conditions when measuring the amount of water held. When an experiment is entirely comparative, the same yarn being used to determine the effect of varying wetting conditions, then it is immaterial which method is used, so long as it is kept constant. This may be illustrated by the results, shown graphically in Fig. 2, for the water held, as determined with 2 and 6 strands, not separated, of 25's grey line yarn spun with varying amounts of twist. The two methods give different values, in confirmation of Table VI, but the variation with yarn twist is identical.

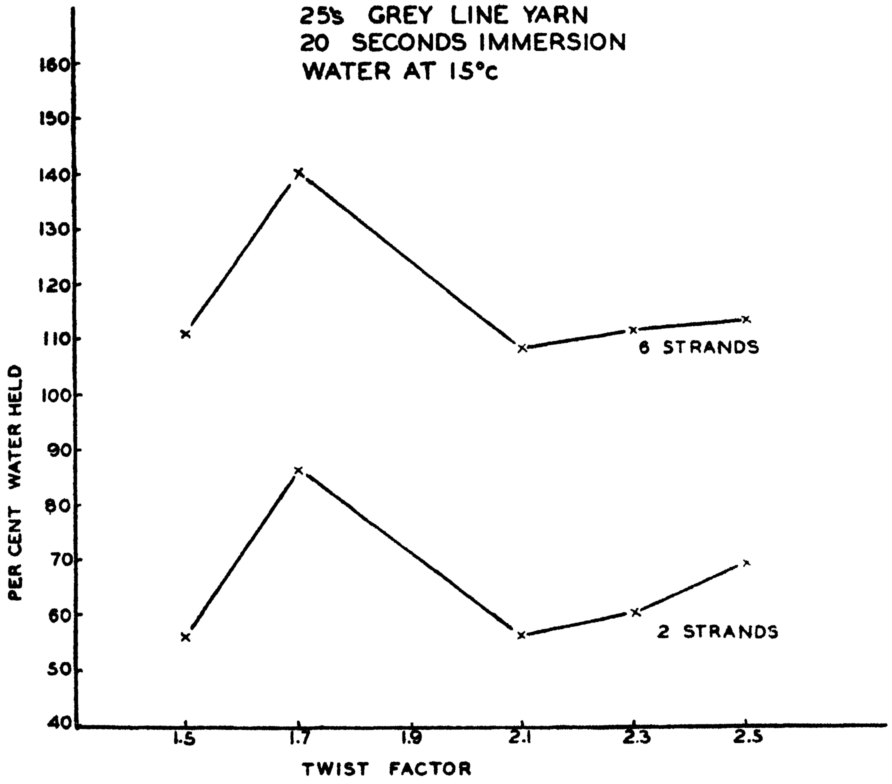


Fig. 2

Table VI
40's line yarn, boiled.
15 Seconds immersion, water at 15° C. Length of strands 15 ft.

Number of Strands	Per cent. Water Held Separated in Water	 Not separated in Water
2	141	166
3	—	193
4	148	206
6	152	212
8	—	226

On the other hand, it would be concluded from this table that when the object of an experiment is the comparison of yarns of different sizes, or of yarns composed of different materials, or in any case where the actual value for the water held by the yarn itself is of the greatest importance, then it would be necessary to determine the water held by the method in which the strands are kept separated. This method is rather difficult to employ without a great deal of trouble, with more than 2 strands. The practice has been adopted, therefore, of performing two tests in such cases, first with 5 or 6 strands 15 feet long to determine the completeness of wetting and again with two strands of the required length, kept separate, to determine the real value of the water held by the yarn.

These tests show that when suitable precautions are taken, the method is capable of giving the desired results with a fair and sufficient degree of accuracy.

WETTING OF YARN AND TIME OF IMMERSION

A number of measurements were made of the completeness of wetting of various kinds of flax yarns on leaving water at different temperatures after times of immersion varying from one-fifth to fifty seconds. In all cases the

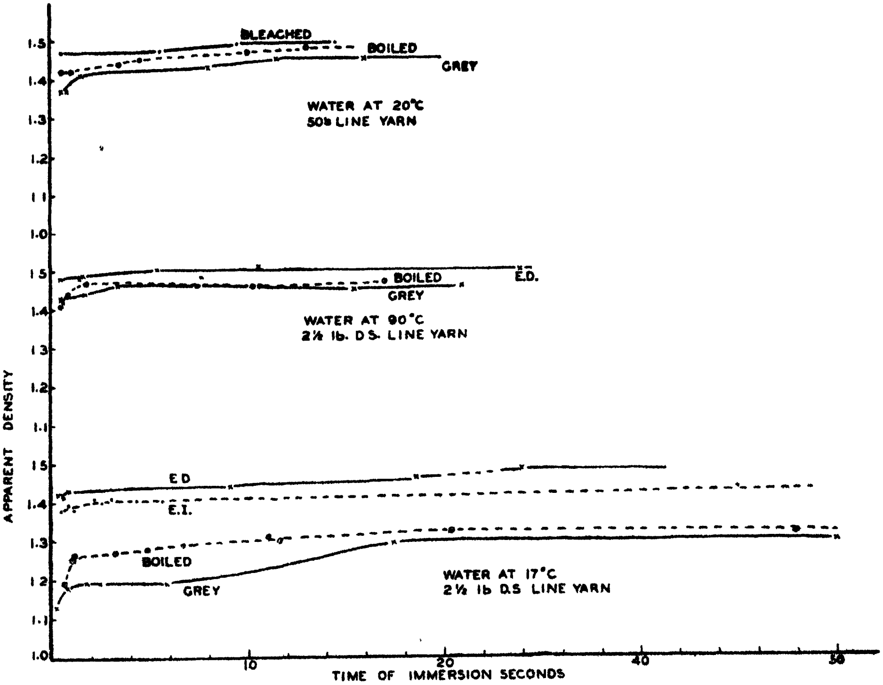


FIG. 3

same general result was obtained, and a few typical cases are illustrated in Fig. 3. The four lowest curves refer to a 2½ lb. D.S. line yarn grey, boiled and bleached E.I. (⅜ white) and E.D. (¾ white), in water at 17° C. (65° F.). Complete wetting in these yarns would be indicated by densities of 1.46, 1·50, 1·50, and 1·51 respectively. In each case the apparent density increases very slowly with increasing time of immersion, from the value given after about half a second to some maximum value given at about 20 seconds. In these samples this maximum apparent density was in all cases less than the absolute, but it remained constant up to 50 seconds immersion. No doubt if the samples had been kept immersed for much longer times, the wetting would have become more complete, but such times are of no interest as regards any material in which absorbency is of importance in its practical use. The middle set of three curves refers to the same yarns but immersed in water at 90° C. (194° F.). The same result is again obtained, only in this case all the yarns are much more completely wetted and the maximum apparent density is shown after a much shorter time of immersion, and the E.D. bleached yarn was completely wetted after 5 seconds. The top set of three curves show similar results in water at 20° C. (68° F.) for a 50's wet spun line yarn, grey, boiled and bleached, for which complete wetting would be indicated by densities of 1·49, 1·49, and 1·52 respectively. Each of these yarns was more completely wetted in this cold water than the corresponding dry spun yarn, but the general result is the same, the attainment of some degree of wetness less than complete, within these limited times of immersion. It may be remarked in passing that the rapidity and completeness of wetting obviously differ considerably in different kinds of yarn, and they increase progressively from grey to full bleach. These points will be discussed more fully later.

The conclusion drawn from these curves appears to be of considerable importance. In the first place it is of importance as regards the method used for measuring completeness of wetting, showing that the results are not liable to serious error due to the passage of time necessarily involved between the emergence from the water and the completion of the density measurement. It indicates that to obtain a definite comparison between different samples, or say the effect of change of temperature on one sample, the time of immersion should be such that they all attain their maximum wetting under the conditions of the test. This condition has been fulfilled in all subsequnet work to be dealt with in this paper; with any new material a series of tests with varying times of immersion were made in order to determine the fixed time of immersion suitable for that material and the conditions to be used. The curves also show that, for practical purposes, when yarn has to be wetted by being run through a bath of liquid at a fixed temperature, a period of immersion of a few seconds will be just as effective as much longer times.

WETTING OF YARN AND TEMPERATURE OF WATER

A number of yarns were tested for completeness of wetting after immersion in water at temperatures varying from 5–100° C. The time of immersion was kept constant at a value sufficient to allow the yarn in cold water to attain its maximum degree of wetting. A few typical cases are illustrated in Fig. 4 showing apparent density plotted against temperature. The apparent density corresponding to complete wetting is shown at the extreme right of each curve. The curves shown do not serve for a direct comparison of the actual completeness of wetting of grey, boiled, and bleached yarns, but each curve may be taken as indicating the variation with temperature of the completeness of wetting which it is possible for the yarn to attain within a limited time.

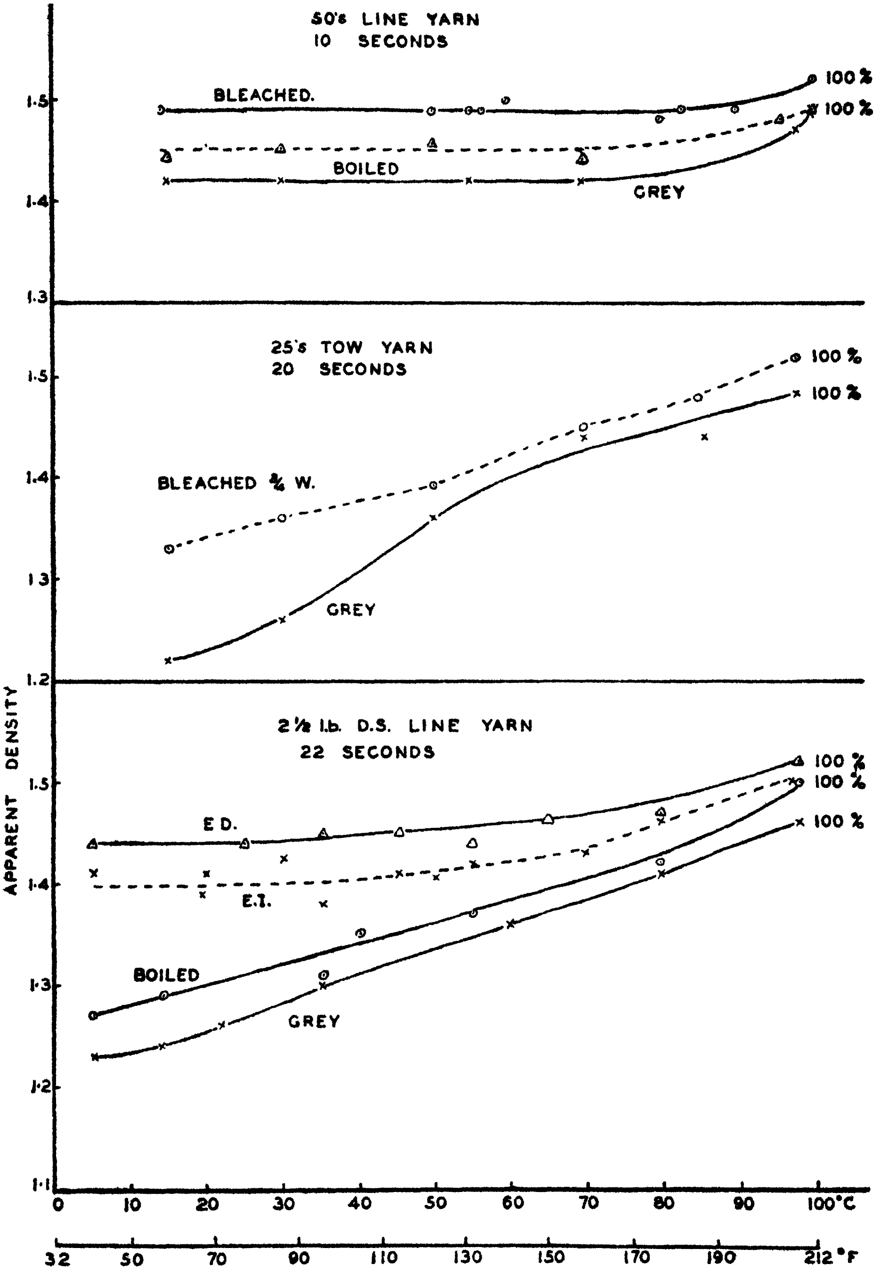


FIG. 4

In all cases complete wetting of yarn can be effected in a very short time with boiling water or water at a few degrees below the boiling point. The rate of change of completeness of wetting with temperature depends on the nature of the yarn, and two distinct types may be observed. When the character of the yarn is such that wetting is (1) far from complete in cold water; increase of temperature then causes a progressive increase in wetting. Grey boiled or partly bleached dry spun yarns or wet spun tow yarns fall within this category. (2) Fairly complete (90% or apparent density over 1·4) in cold water; increase of temperature then causes no observable increase in wetting until a certain temperature is exceeded, but then wetting increases slowly to completion with increase of temperature to the boiling point. Thus with bleached dry spun line yarn, wetting does not increase appreciably until the temperature rises above 50° C.; with fine grey, boiled, or bleached wet spun line yarns, wetting does not increase noticeably until the temperature exceeds 70° C.

These results are of importance in defining practical working conditions in any process in which yarns have to be wetted by simple immersion or by running through a bath. Unless long continued soaking or mechanical working or the application of pressure by rollers is resorted to, complete and regular wetting can only be attained in water which is nearly boiling. The results also clearly define the temperature conditions which are most desirable for comparative laboratory tests of the ease of wetting of different yarns. It is clear that the differences in wetting which may exist for various reasons, will be greater the lower the temperature at which the experiment is made, and at 100° C. there will be no difference. Hence by using a low temperature, small differences in ease of wetting will be more readily detected and so greater sensitivity can be obtained. From the point of view of deriving information relative to the behaviour of the yarn in fabric, low temperatures are also of greatest interest; whether the fabric is a garment or a towel for personal use or for drying dishes, it would seldom be used for absorbing water above body temperature, say 30° C., and more often the water would be colder than this.

EFFECT OF BOILING AND BLEACHING ON YARN ABSORBENCY

Reference has already been made in the discussion of Figs. 3 and 4 to the relative behaviour of grey, boiled, and bleached yarn, showing that under similar wetting conditions the completeness of wetting increases in this order. Certain differences in the effect of temperature on bleached and grey or boiled yarns of different types were also pointed out. Other interesting differences between the effect of temperature on the absorbent properties appear from consideration of the per cent. water held by the yarns after a fixed time of immersion at different temperatures. These results are shown in Fig. 5 for the same yarns as are referred to in Fig. 4. It will be seen that for each of these three types of yarns in the boiled and bleached states, the per cent. water held decreases with increase of temperature up to about 50° C., and then remains fairly stationary. That is, over the low temperature range which has little effect on the completeness of wetting during a fixed time of immersion, the water held decreases, but over the high temperature range in which completeness of wetting increases, the per cent. water held does not change. The 25's bleached tow yarn shows greater increase in completeness of wetting and less decrease in per cent. water held with increase of temperature than the other two yarns. The grey wet spun yarns show a different behaviour, the per cent. water held first increasing with increase of temperature and then decreasing. In both cases the water held by the grey yarn was less than that held by the bleached yarn. The grey dry spun yarn, however, shows a still further difference in behaviour, giving a rapid increase

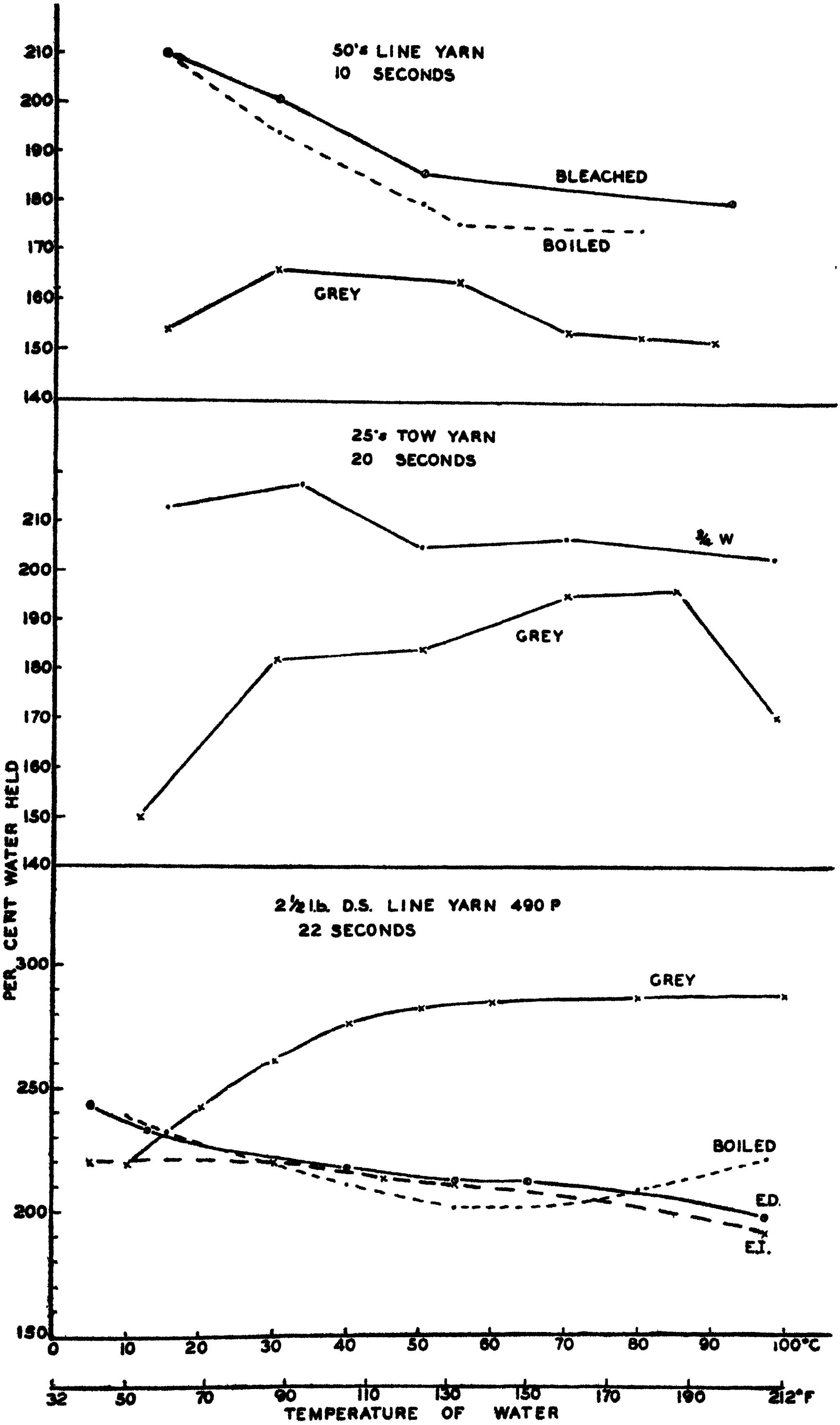

50's LINE YARN
10 SECONDS
BLEACHED
BOILED
GREY
25's TOW YARN
20 SECONDS
¾ W
GREY
2½ lb. D.S. LINE YARN 490 P
22 SECONDS
GREY
BOILED
E.D.
E.I.
PER CENT WATER HELD
210
200
190
180
170
160
150
140
300
250
150
0
10
20
30
40
50
60
70
80
90
100°C
32
50
70
90
110
130
150
170
190
212°F
TEMPERATURE OF WATER

FIG. 5

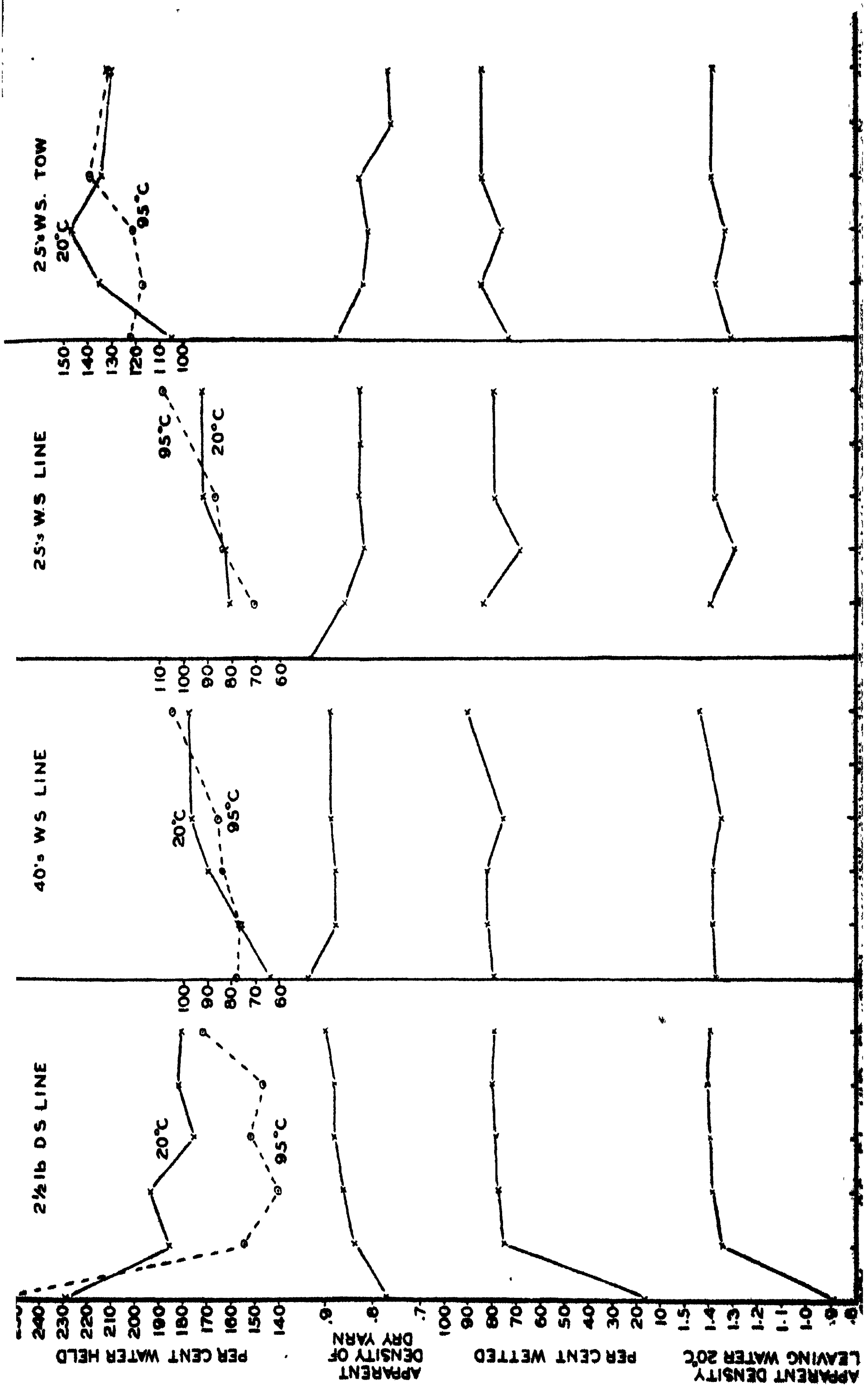
in per cent. water held with increase in temperature, up to a maximum value which is much greater than the value for the corresponding boiled or bleached yarn.

These results do not appear to be in agreement with expectations. Assuming that the only action of the water is to flow over the fibre surface and so wet the fibre and cause displacement of air from the interspaces, it would be expected that the per cent. water held would increase with increased completeness of wetting. Before attempting to explain this apparent discrepancy some further results may be considered, which were determined to confirm and elucidate the effect.

Several yarns were available in the grey, boiled, and various stages of bleaching. The completeness of wetting was measured in each case in water at 20° C., and the per cent. water held after immersion in water at 20° C. and 95° C. The results are shown graphically in Fig. 6. including the apparent density of the dry yarn, and the derived figure for the percentage of fibre surface wetted. The changes in apparent density of the dry yarns on boiling and bleaching are not so large as to cause any difference in the relative order of the samples as regards completeness of wetting, whether this is regarded in terms of per cent. wetted or in terms of apparent density in water after immersion. This is clearly shown by the two lowest sets of curves, which are identical in shape. They show that in wet spun yarn under these conditions of immersion at 20° C., there is a gradual increase in the completeness of wetting produced by boiling and by successive stages of bleaching. In the case of the dry spun yarn, there is a very marked increase in the ease of wetting after boiling, followed by a further gradual increase by successive stages of bleaching.

The results of measurements of the per cent. water held at 20° C. and 95° C. after fixed times of immersion, are shown by the top set of curves. Thus the dry spun line yarn holds more water at 95° C. than at 20° C. in the grey state; the amount held by the boiled and bleached yarns is fairly constant at both temperatures and they hold less water at the higher than at the lower temperature. In the case of the wet spun yarns, at both temperatures the amount of water held increases on boiling and bleaching up to the ½ W stage, when the value remains fairly constant; as with the dry spun yarn, the grey yarn holds more water at 95° C. than at 20° C. This could be attributed to the more complete wetting at the higher temperature, which as shown by Fig. 4 differs considerably in the case of grey yarns.

The apparent discrepancy previously noted, that the more completely wetted boiled and bleached dry spun yarns hold less water than the very incompletely wetted grey yarn, is thus confirmed. The reason for this becomes clear from consideration of the values for the apparent density (compactness) of the dry yarns, which are plotted as the second set of curves shown from the top. It at once appears that there is an approximate inverse relationship between these curves and those for the per cent. water held. This suggests that the value for the per cent. water held depends not only on the completeness of wetting but also on the amount of free space between the fibres in the yarn capable of being filled by water. In addition, of course, water is held as a surface layer, which will vary in yarns of different diameters; in the case of the dry spun yarns, the boiled and bleached yarns are more compact and so, although more completely wetted, cannot hold so much water as the less compact and less completely wetted grey yarn. Wet spun yarns on the


25's WS. TOW
20°C
95°C
25's W.S LINE
95°C
20°C
40's WS LINE
20°C
95°C
2½ lb DS LINE
20°C
95°C
150
140
130
120
110
100
110
100
90
80
70
60
100
90
80
70
60
240
230
220
210
200
190
180
170
160
150
140
PER CENT WATER HELD
.9
.8
.7
APPARENT DENSITY OF DRY YARN
100
90
80
70
60
50
40
30
20
10
PER CENT WETTED
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
APPARENT DENSITY LEAVING WATER 20°C

other hand become less compact as well as rather more completely wetted, and so can hold a greater amount of water on boiling and bleaching. Wet spun tow shows a greater increase than line in the water held after boiling and this appears to be due to the boiling causing a larger increase in the rate of wetting of the tow yarn.

The relation between compactness and water held is further indicated by comparison of the values for the 25's line and tow. They are approximately equal in completeness of wetting, but the tow yarn holds nearly double the amount of water. This is partly due to the tow yarns being less compact and therefore having a greater air space in the interior, and also in consequence the yarns are of greater diameter and so hold more on the surface.

It is consistently shown by the measurements that boiled and partly bleached yarns hold less water at a very high temperature than at a low temperature, although more completely wetted, but the effect tends to disappear in more completely bleached yarn.

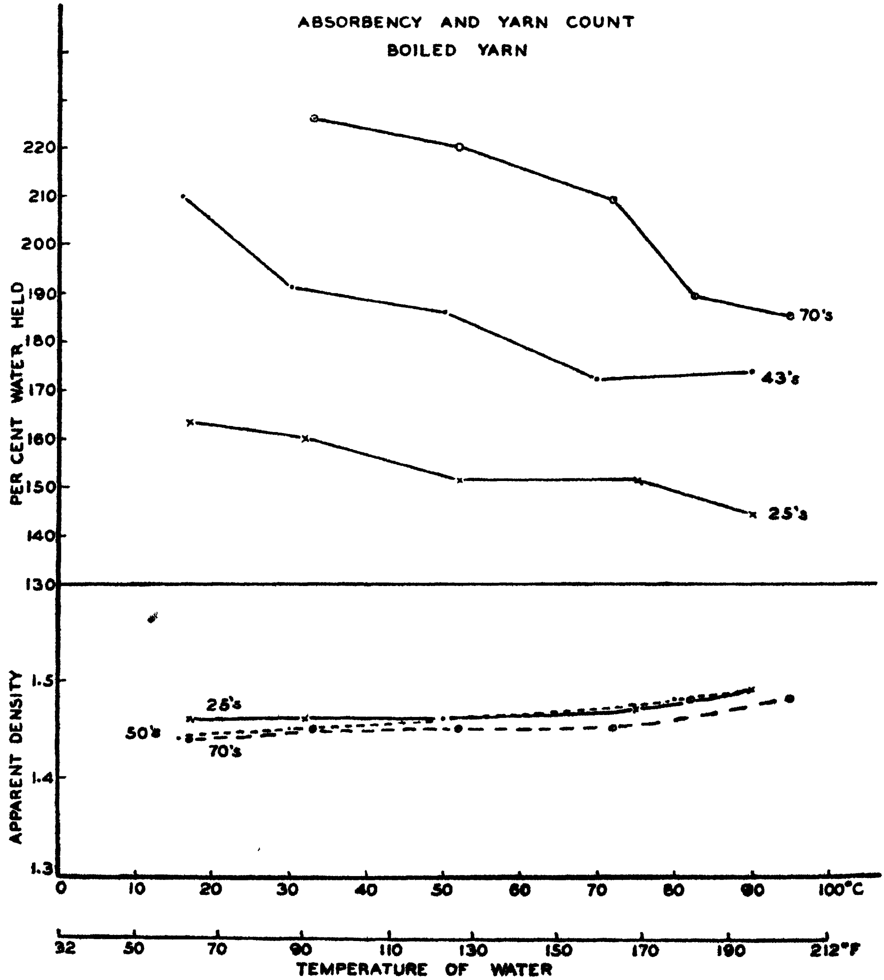


FIG. 7

EFFECT OF YARN COUNT

The results of some measurements on boiled wet spun line yarns of different counts at a series of temperatures are shown graphically in Fig. 7. They all show the same behaviour as noted previously, a gradual increase in completeness of wetting and a gradual decrease in the per cent. water held with increase of temperature. The differences in rate of wetting by the yarns of different count are slight, but tend to show a slight superiority in the coarser yarns. Considerably greater differences are shown in the per cent. water held by these yarns of different count, increasing with increasing yarn count.

As completeness of wetting and the compactness would be very closely equal in these yarns of varying count, the differences in the per cent. water held must be due to variations in the amount of water held on the yarn surface under these conditions.

Table VII

Absorbency of yarns from various kinds of flax yarn.

40's lea. Grey line. Immersed 12 seconds.

Sample No.	Kind of Flax	Apparent Density leaving Water at 20° C.	Per cent. Water Held leaving Water at 20° C.	95° C.
295 P	Baltic	1·42	77·2	92·6
297 P	Baltic Irish	1·41	57·5	105·5
296 P	Baltic	1·40	55·9	84·9
302 P	Courtrai Dew Retted	1·39	91·0	94·4
301 P	Dutch Dew Retted	1·38	86·2	91·1
300 P	Blue Dutch Water Retted ...	1·36	50·1	102·1
299 P	Irish Water Retted	1·31	39·6	86·5
298 P	Courtrai Water Retted... ...	1·30	59·1	86·4
303 P	Flemish Dew Retted	1·10	29·5	84·6

ABSORBENCY AND QUALITY OF FLAX

The results of some measurements of the completeness of wetting after 12 seconds immersion at 20° C. and of the water held after immersion in water at 20° C. and 95° C. are given in Table VII for a set of grey wet spun line yarns all spun to 40's lea from flaxes of various kinds. The measurements were all made under the same conditions. The samples have been arranged in order of decreasing completeness of wetting after immersion, and this varies considerably. There appears, however, to be no consistent relation between kind of flax or method of retting and the completeness of wetting. It is therefore probable that the differences shown by the samples are due to some slight difference in the characteristics of the yarns produced under similar conditions from the different flaxes. For example, smoothness and compactness might be expected to vary according to the fineness of the fibre strands and the relative proportions of fibres of different lengths. That such differences can produce marked differences in rate of wetting has already been shown by the results discussed in connection with line and tow yarns. Such differences appear to be largely temporary and only show at low temperatures; the results in Table VIII for the per cent. water held at 95° C., when all the yarns would be almost completely wetted, show much less variation with the different flaxes.

EFFECT OF TWIST ON ABSORBENCY OF YARN

Extensive measurements were made on three different yarns, 2½ lb. D.S. line, 25's W.S. tow and line from the same lot of fibre. Each of these yarns was spun with six different twists, and samples were available in the grey,

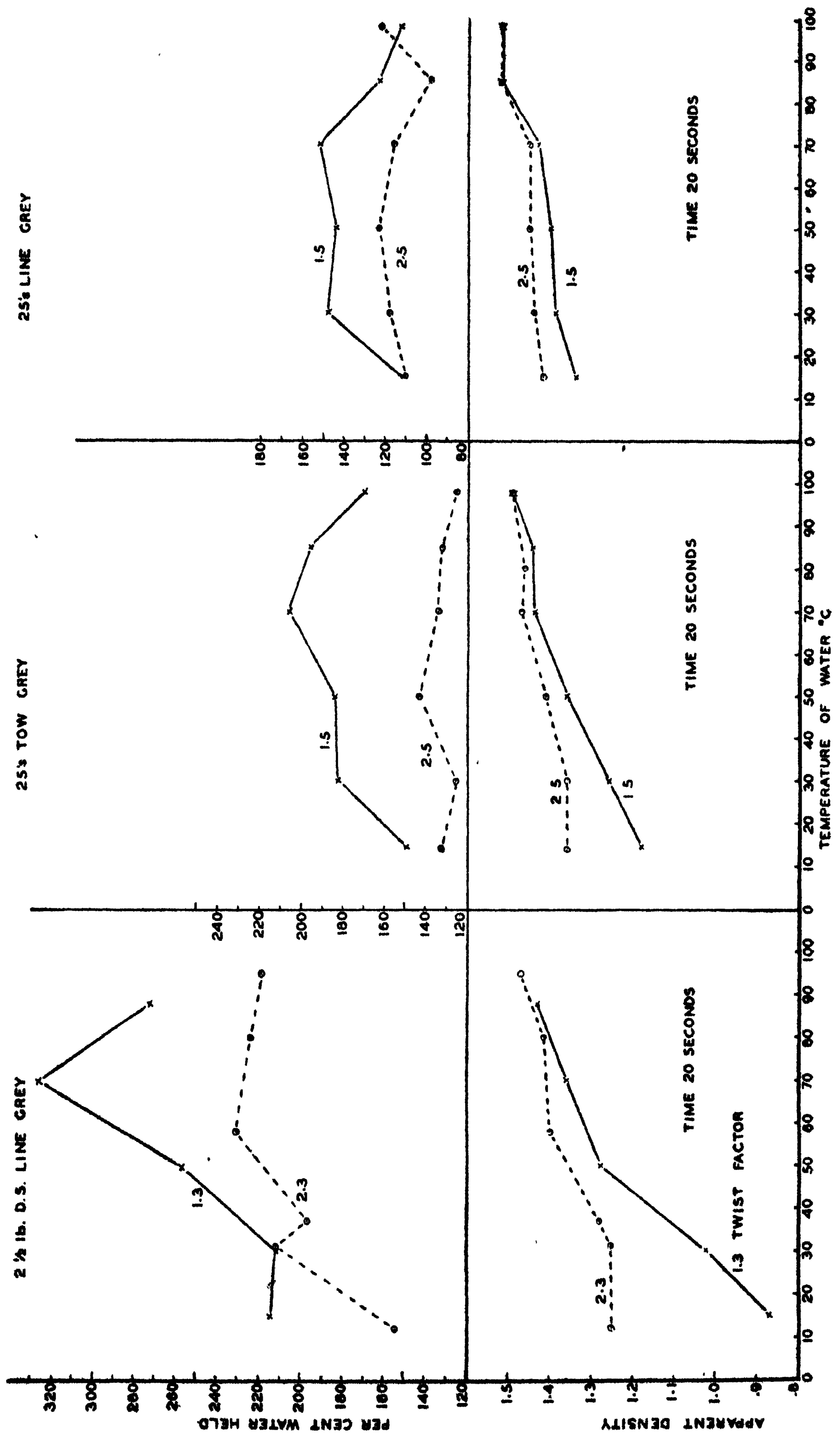
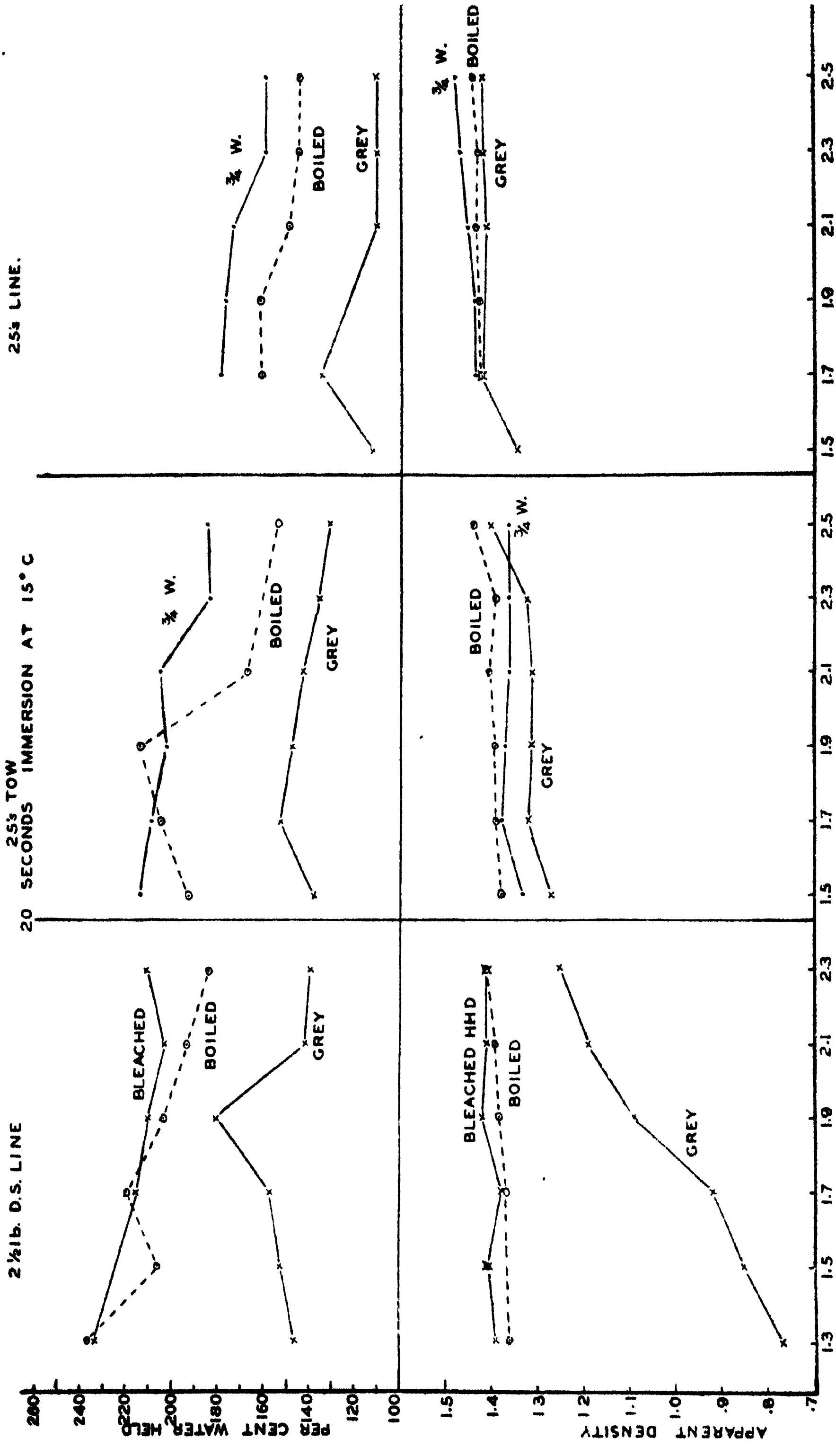

2 ½ lb. D.S. LINE GREY
25's TOW GREY
25's LINE GREY
PER CENT WATER HELD
APPARENT DENSITY
TIME 20 SECONDS
TIME 20 SECONDS
TIME 20 SECONDS
TWIST FACTOR
1.3
2.3
1.5
2.5
TEMPERATURE OF WATER °C
0
10
20
30
40
50
60
70
80
90
100
320
300
280
260
240
220
200
180
160
140
120
180
160
140
120
100
80
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8

FIG. 8


2½lb. D.S. LINE
25s TOW
25s LINE.
20 SECONDS IMMERSION AT 15° C
PER CENT WATER HELD
APPARENT DENSITY
NOMINAL TWIST FACTOR IN YARN
BLEACHED
BOILED
GREY
BLEACHED HHD
¾ W.
280
240
220
200
180
160
140
120
100
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
1.3
1.5
1.7
1.9
2.1
2.3
2.5

boiled and bleached conditions. The results have been summarised in such a way as to bring out the comparative effects of twist on these different types of yarn in the grey, boiled, and ¾-white states.

Fig. 8 shows the completeness of wetting and the per cent. water held after a fixed time of immersion in water at different temperatures, for the highest and lowest twist grey yarns.

The curves for change of completeness of wetting are of the normal type, a progressive increase with increase of temperature. In each case the yarn of high twist is more completely wetted than that of low twist and the wetting of the low twist yarn changes with temperature much more than that of the high twist. With each of these three yarns, the low twist holds more water than the high twist yarn even at low temperatures where the latter was markedly more wetted. The per cent. water held by the high twist wet spun yarn seems to be fairly constant at all temperatures; the same applies to the dry spun yarn at all except the lowest temperatures. The per cent. water held by the low twist yarn shows a consistent increase with increase of temperature up to about 70° C. and then decreases. These results again demonstrate that the per cent. water held, as measured by this method, is very largely dependent on the condition of the exterior yarn surface, and this effect is so pronounced as to be able to more than counteract differences in completeness of wetting. The high twist yarns present a hard smooth surface on which the water can run fairly freely, whereas in low twist yarns the surface is rougher and possibly more hairy, so the water would not run freely. In the experimental method employed the yarn leaves the water at a steep angle and there would be a constant tendency for the water to run down the yarn surface and back into the water bath. Such an effect would explain the results obtained in these experiments, and also explain some of the previous results, such as the differences between the yarns spun from different flaxes, or between tow and line.

The results of measurements of the completeness of wetting and of per cent. water held after immersion for 20 seconds at 15° C. are shown graphically in Fig. 9 for three yarns, grey, boiled, and bleached, spun with six different twist factors. These measurements were all made under similar conditions. In the grey state, the completeness of wetting by this fixed immersion increases with increase of yarn twist. This is most marked with the dry spun line yarn and least with wet spun line. In each case a slight increase in ease of wetting with increase of twist is shown by the boiled yarns, but this is less marked with the bleached yarn. On the whole the results for per cent. water held by the boiled and bleached yarns show a general decrease with increase of twist; in the grey yarns the water held increases to start with, where the wetting shows the greatest increase in completeness of wetting, and then decreases in the same way as the boiled and bleached yarn.

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THE JOURNAL OF THE
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TRANSACTIONS

21—A VISUAL AND TACTILE ANALYSIS OF TYPICAL BRADFORD WOOL TOPS

By Henry Binns, F.T.I.

INTRODUCTION

"In our own industry there are judgment factors which would not exist under other forms of industrial organisation. As a simple case in point: a spinner buying tops is called upon to judge the top he has offered for many factors, which are already known by the supplier—the topmaker. The manufacturer when buying yarns has to exercise his commercial judgment for factors which are already known by his supplier, the spinner."

This statement made to the author, by a man of wide experience in the wool textile trade, serves to emphasise the difficulties likely to be met with in the course of daily business transactions, and incidentally stresses the need of sound judgment. The wool-buyer must have a basis on which to determine his estimate of quality and price. Not only must he consider "yield" which varies according to the country of origin, and the character of the wool, but in addition, he must consider the general appearance, fineness, length, handle, soundness, elasticity, colour and lustre, waviness, and suppleness of each lot under offer.

Classing usually takes place on the station, but the sorting into various qualities by experienced sorters, mainly by sight and touch, is done in manufacturing centres. Barker and Winson[1] have shown that in the judgment of the wool sorter "any attempt on his part to form a gradation of finenesses will result in a scale in which successive finenesses increase in geometrical progression. This, as we have shown, is exactly the case in practice in all countries. It must, of course, not be forgotten that two senses are employed in wool-sorting, *viz.* sight and touch, and that Fechner's Law apparently is applicable only to the former. Thus the result of a selection employing the visual sense would result in a gradation of wool into classes whose mean finenesses are in geometrical progression, The tactile sense may in some way be related to the auxiliary question of 'handle'". The degree of fineness, therefore, is considered to be a provable fact. Much uncertainty surrounds the question of "handle" usually associated with the word "softness".

Commission wool-combing prices are based on three general classifications of fineness and take no account—except indirectly—of softness. Even this selection by diameter is, in practice, not always easy owing to blending of various types in one top and it has been found necessary to set up an organisation to decide by judgment and by mechanical tests to which category a particular top belongs. A blended top, the contents of which are known only to the top-maker, for a particular purpose, and influenced by severe competition in price, presents an ideal psychological problem in which the factors are numerous, complex, irregular and fluctuating. Whatever may be the possibilities of determining quality by fineness, they are simple, in our present state of knowledge, compared with variations in softness. Tops, hard to the touch, will measure, by optical means, thicker in diameter than they appear to the eye—therefore "handle" must enter into the consideration of degrees of fineness.

Some of these changes in the character of "handle" as determined by tests have been already published.[2,3,4,5] The aim of the present investigation is to attempt a direct comparison of fineness and softness by the judgments of sight and of touch independently, from one set of standard samples. This seems to be best obtained in top form. In grease, test samples of comparable uniformity cannot be obtained. When fibres are twisted, woven or interlaced, important and undesirable factors cause confusion of judgment.

THE SAMPLES, INSTRUCTIONS, AND METHODS

At the author's request, the British Wool Federation kindly supplied samples of tops which are recognised as independent standards. These were selected, with the utmost care, by representative members and were accepted by the U.S.A. Department of Agriculture as 80's, 70's, 64's, 60's, 58's, and 56's, typical Bradford tops.

For the *sight* judgments six black velvet boards 9 in. × 4 in. were used, the drawings being made anew on each occasion of testing; secret identication marks were placed on the back of each board.

For the *touch* judgment about 12 in. of each top were employed, with swing tickets on which were marks comparable with those for sight.

The *instructions* were as simple as possible, *viz.*, to grade the samples—

(1) In order of fineness by sight, and

(2) In order of softness by touch.

In the case of sight the boards could be moved without touching the fibres. When touch was used, a method of holding and feeling the samples was suggested, mainly to avoid seeing the materials. All, even the children, found it more interesting to look out of the window for the touch tests and appeared to take the experiment quite seriously. The complete test consisted in repeating each sight and touch judgment five times. Usually a sight test was alternated with a touch test. In all cases the samples were mixed by the experimenter after each trial.

Spearman's Correlation "Footrule" or R. Method has been used throughout in the correlations.[2] Two measures are presented, one being the ten intercorrelations of five gradings of the tops and showing the consistency of that group of judgments; the other, the average grading of the five trials with the Federation Standard. The "probable error" throughout is ± ·18.

The grading of the materials is stated in absolute placings (1 to 6) by the judges or in decimals of those placings. The measure of reliability is the percentage difference between the average placings of the best and worst materials in the set of samples.

A careful examination of the statements of errors as compared with the coefficients of correlation developed by Spearman in his Footrule Formula appears to the writer to indicate that the tabulation of errors is more refined and easier to grasp than the statistical method. This is partly due to the fact that a definite grading of the samples was known at the outset and afterwards proved by the tests.

THE JUDGES

The following took part in the inquiry—

Five Topmakers, selected because of their reputation in the trade.
Five (Wool Buyer, Wool Merchant, Waste Merchant, Spinner, and Manufacturer of Dress Goods), known from previous tests to be good or indifferent judges by touch.
Five Men without wool-trade experience }
Five Women without wool-trade experience } by chance selection.
Five Students of Textile Department, Bradford Technical College.
Five Students of the College of Art and Crafts, Bradford.
Five Boys average age $11\frac{9}{12}$ at a Bradford Elementary School.
Five Girls average age $11\frac{6}{12}$ at a Bradford Elementary School.
(The students and children were selected by their Heads of Departments, all being unknown to the writer.)
One Experimenter with repeated tests.

THE RESULTS

The results, especially those of girls, proved so illuminating that a paper entitled "A Measure of Tactile Sense" was presented by the author at the Aberdeen Meeting of the British Association for the Advancement of Science in September 1934.

Disregarding all degrees of difference, Table I shows that all the groups of five persons making five trials, each correctly graded the samples by sight, and only two incorrectly by touch in spite of the fact that individuals in each group gave some incorrect results in each trial.

Table I

	Sight						Touch					
Group of	80's	70's	64's	60's	58's	56's	80's	70's	64's	60's	58's	56's
5 Topmakers	1	2	3	4	5	6	1	2	3	4	5	6
5 Trade—Various	1	2	3	4	5	6	1	2	3	4	5	6
5 Technical Students	1	2	3	4	5	6	1	2	4	3	5	6
5 Art and Crafts Students	1	2	3	4	5	6	1	2	3	4	5	6
5 Men	1	2	3	4	5	6	1	2	3	4	5	6
5 Women	1	2	3	4	5	6	1	2	3	4	5	6
5 Boys	1	2	3	4	5	6	1	2	4	3	5	6
5 Girls	1	2	3	4	5	6	1	2	3	4	5	6
Experimenter	1	2	3	4	5	6	1	2	3	4	5	6

In the case of sight judgments, the boys and girls at first reversed 80's and 70's qualities—indeed 8 of the 10 children made this error. The tests were first applied to these groups and the draws were not changed during the experiment. Subsequent draws on other samples were criticised by one of the best trade judges who complained that the shoulder was too thick, and the long and strong fibres were shown up too prominently. Though other draws did not entirely support his contention, it seems probable that the children were disturbed by some such lack of skill on the part of the experimenter.

The two qualities were again taken to the school for rejudging by the same children, who were lined up outside the Headmaster's room. They came in one at a time and 8 out of 10 without any hesitation selected the 80's quality as the finest. As the action was so rapid in one case, the boy was asked if he had taken sufficient care; this upset him completely, and he seemed unable afterwards to make up his mind. This effect of the power of suggestion has been investigated before.[5] The final gradings of samples were therefore altered to correct the error in drawing made by the experimenter and Table I shows these gradings only.

No such criticism could apply to the touch tests, as the tops were very carefully handled before and during the experiment; each judge had entire control during the test. The technical students reversed 64's and 60's in the proportion of 50 and 53 respectively— a very narrow margin—as determined by the Percentage Standard on Table II; this is a rational error as will be explained later. They correctly placed 64's at 57 and 60's at 43 by sight. In the case of the boys the judgments were wild, as instanced by the fact that the 56's were placed in the 3rd, 4th, 2nd, 6th and 6th positions by different boys. The measure of reliability of the boys was 64 and that of the girls 96, the latter only making two slight reversals and these were on the same qualities, and apparently for the same reason as for those of the technical students.

The degrees of difference between the sample tops are indicated in Table II. The average placings given (1·20, 1·88, etc.) are the average of five trials by the five persons in each group.

Table II

GROUP	SIGHT						Measure of Reliability	TOUCH						Measure of Reliability
	80's	70's	64's	60's	58's	56's		80's	70's	64's	60's	58's	56's	
Topmakers	1·20	1·88	2·92	4·00	5·00	6·00	96	1·04	1·96	3·40	3·60	5·08	5·92	97
Trade—Various ...	1·40	1·96	2·76	4·04	5·00	5·80	89	1·08	2·12	3·16	3·84	4·84	5·96	97
Technical Students ...	1·00	2·00	3·16	3·84	5·32	5·68	94	1·00	2·12	3·48	3·36	5·24	5·80	96
Arts and Crafts Students	1·44	2·36	2·76	4·00	4·92	5·52	82	1·12	1·88	3·26	3·76	5·08	5·88	95
Men	1·96	2·20	2·36	3·76	4·92	5·80	77	1·08	2·32	3·28	3·72	4·84	5·80	94
Women...	1·32	2·24	2·52	4·16	5·32	5·44	83	1·28	1·88	3·44	3·68	5·24	5·48	84
Boys	1·28	2·00	3·32	3·72	5·20	5·48	68	1·60	2·72	3·92	3·60	4·92	4·24	64
Girls	1·48	2·28	3·16	3·64	4·64	5·80	72	1·08	2·16	3·32	3·56	5·00	5·88	96
Average Place ...	1·48	2·12	2·87	3·90	5·04	5·69	84	1·16	2·15	3·40	3·64	5·03	5·62	89
Grade of Fineness and Softness	1	2	3	4	5	6	—	1	2	3	4	5	6	—
Percentage Standard ...	100	80	60	40	20	0	100	100	80	60	40	20	0	100
Group Averages ...	89	81	63	42	19	6	83	97	77	52	47	19	8	89
Experimenter	82	80	77	40	16	5	77	98	76	55	47	23	1	97

The 80's quality is given a standard of 100 and the 56's quality one of 0; between are 80, 60, 40, and 20. If each judge graded correctly, the measure of reliability would be 100; the actual average of 8 groups is 84 to sight and 89 to touch—both high results.

The measure of reliability to sight might be anticipated as the result of natural and acquired ability—females being more sensitive than men—but with experience and training dominating all. The experimenter, obviously a poor judge on sight, failed to realise any perceptible difference in the three best qualities; advancing age, no doubt, being some cause for this defect.

Turning now to the touch judgments it will be noted that, in the measure of reliability, all but two of the groups—including those of the experimenter—are nearly perfect. The women are let down by the erratic judgments of one of them, whilst one boy with a final grading of + ·08, made merely a pure chance arrangement.

The factors in touch judgments of tops are quite different from sight judgments. In touch, an untwisted sliver, an inch thick, composed of fibres of approximately the same fineness but of varying length is held by one hand, whilst the whole of the surface of the palm, fingers and thumb of the other may be used to stroke the fibres in mass and slightly disturb them by muscular action. Between each quality there is a massed degree of softness. But in sight judgment an estimation of the relative proportion of minute differences of fineness has to be made—a mass of short, shoulder fibres tends to stress fineness whilst odd coarse fibres of greater length tend to suggest a lower quality. The waviness or straightness of a few fibres is also apt to disturb judgment.

After consideration of the average sight and touch judgments of 40 persons compared with the percentage standard, two qualities, 64's and 60's, deserve particular attention—

	64's	60's	Difference
Percentage standard	60	40	20
Sight average	63	42	21
Touch average	52	47	5

It would seem, therefore, that the original selectors of these standards had judged mainly by diameter of fibre. In the other four qualities fineness and softness are approximately equal. In previous experiments it has usually happened that the average of a sight and a touch judgment was approximately equal to a full, unfettered judgment of the same materials. Hence it would appear that on a commercial valuation basis these samples of 64's and 60's have little more than a half—instead of a whole—quality between them.

In contrast to his poor sight judgments, it will be noted that on handle the experimenter's definition is better than that of the experts—the topmakers—showing that the one sense may work quite independently of the other. Elsewhere[6] the writer has shown also that the sensitivity of one hand may be quite different from that of the other.

Another form of comparison is given in Table III which covers—

(*a*) The consistency of group judgments arrived at by averaging the ten inter-correlations of five judgments;

(*b*) The average grading of five persons, giving five judgments each, compared with the recognised Federation standard;

(*c*) The relationship of sight to touch as represented by the coefficient of correlation.

Table III

	SIGHT			TOUCH			COEFFICIENT OF CORRELATION	
							Sight & Touch	
	Errors	Inter-correlation	Standard	Errors	Inter-correlation	Standard	(*a*)	(*b*)
Topmakers	2	1·00	1·00	5	1·00	1·00	1·00	1·00
Trade—Various	12	·98	·95	7	·94	1·00	1·00	·95
Technical Students ...	4	1·00	1·00	9	·97	·99	·99	·97
Art and Crafts Students	16	·85	·93	6	·97	1·00	1·00	·92
Men	19	·81	·94	13	·89	1·00	1·00	·90
Women	14	·91	·99	14	·88	·97	1·00	·97
Boys	15	·85	·98	32	·64	·54	·99	·59
Girls	19	·88	·87	7	·93	·98	1·00	·84
Average	13	·90	·96	12	·90	·93	1·00	·89
Experimenter	15	·93	·94	10	·94	1·00	1·00	—

Sight and touch would appear to work in the closest co-operation, as shown in the last column of their co-efficients, and from these the experimenter shows little variation.

The errors afford the simplest basis of comparison. The topmakers and technical students, both groups trained top-judges, show twice as many errors on touch as on sight, although their figures are the lowest in both columns. It would appear that experience has refined both sight and touch judgments. The women and men show little variation between the senses, but the girls are very definitely better on touch than the boys.

A PRACTICAL PROBLEM SOLVED BY THE MEASUREMENT OF TOUCH

On page T335 attention was drawn to the small difference in softness, 5% instead of 20%, between the 64's and 60's qualities. After these experiments were completed it occurred to the author that some effort should be made to find the cause of this discrepancy. The original statement was allowed to remain in order to afford a contrast to the logical solution hereunder included.

With a view to tracing any cause, other than softness, for the difference between the 64's and 60's qualities, samples of each top, carefully measured 12 inches long, were submitted to the Bradford Conditioning House for determination of weight. This, indirectly, should be a measure of bulk, as fineness and lightness are usually highly correlated with the thinness of the slivers.

In addition, the experimenter tested these lengths of tops for bulk by handle five times. Then each top was held separately at one end, the sliver being allowed to bend by its own weight; the ease of bending denoted a lack of stiffness. The thicker the sliver the more difficult would it be for it to fall easily. The results are set out in Table IV.

Table IV

	80's	70's	64's	60's	58's	56's
Weight—grams	3·908	3·940	4·623	4·353	4·913	5·532
„ percentages ...	100	98	58	75	39	0
Grading	1	2	4	3	5	6
Smallest bulk—touch ...	100	76	8	64	32	20
Grading	1	2	6	3	4	5
Ease in bending	100	60	40	80	20	0
Grading	1	3	4	2	5	6

It would appear that the 64's quality was heavier, decidedly bulkier, and much stiffer than the 60's quality; the inference being that the sliver of 64's was thicker than the 60's. Other factors than softness had obtruded themselves.

It was felt that if touch can be measured there should be direct evidence and proof of its authenticity. In consequence the records of 3 groups of ten persons each were selected from the 40 subjects, disregarding age, sex and training; these had varying degrees of tactile sense.

Group (*a*) Excellent tactile sense (0-6 errors);

Group (*b*) Moderate tactile sense (10–16 errors); and

Group (*c*) Poor tactile sense (18–44 errors).

Table V gives the average results.

Table V

	Average Errors	64's	60's	Difference
Percentage Standard	—	60	40	+20
Group (*a*) excellent	2	58	43	+15
Group (*b*) moderate...	13	50	45	+ 5
Group (*c*) poor	29	42	52	−10
"Sight" group averages (40) ...	—	63	42	+21
"Touch" group averages (40) ...	—	52	47	+ 5

The bulk and weight of the 64's quality does not appear to have disturbed the very fine sensitivity of the "excellent" group, the figures being close to the Federation standard and also to the averages of all the subjects (40) by sight. It should be possible, therefore, to say definitely that the fineness and softness of these two qualities are highly correlated and both are approximately what they profess to be. It will be noted that the "moderate" group is influenced by the bulk factor, whilst the "poor" group reverses the position of the two samples, making the 60's half a quality better than the 64's.

WOOL INDUSTRIES RESEARCH ASSOCIATION INVESTIGATION

These samples were submitted to the Wool Industries Research Association for the determination of their absolute values as regards fibre fineness. The attached report on work carried out by Miss A. L. Walker, B.Sc., A.Inst.P., of the wool-measurement Department, embodies their results. I am grateful to the Association for this valuable piece of work which involved the examination of about 10,000 individual fibres.

Report

In order to determine the average fineness of the six samples of wool by means of the weight per unit length method, the technique used by Winson and described in his paper, "A Comparison of the Finenesses of British and Continental Standards for Combed Tops" (*J. Text. Inst.*, **22**, 1931) was employed.

In each case duplicate samples of 500 fibres, each 3 cms. in length, were counted out and the dry weight calculated from the mean of the two results, as shown in Table VI. This was done, for each type of wool, by taking a gramme sample, subjecting it to the same treatment as the two bundles of counted fibres and then drying it in a stream of dry air at 105° C. The weight of the bundles together with that of the gramme sample was ascertained under constant humidity conditions and the dry weight of the latter. Hence the dry weight of the bundles and finally the dry weight of 10 metres of fibres could be calculated.

The International Wool Conference in 1929 decided to express fineness in terms of weight in milligrammes of 10 metres of fibres at a regain of 18¼ per cent. Table VII shows the results for the six samples expressed in these units in column 2, and column 3 gives the logarithms of the respective values, so that they may be compared with the standard curve for British Selected Combed Tops.

In order to determine the position on the scale of quality numbers of any samples, the point A (Fig. 1) corresponding to the value for $\log_{10} \frac{W}{L}$ for this sample is marked on the ordinate and a line drawn parallel to the abscissa. This line will cut the standard curve at some point, say N, and another line is then drawn parallel to the ordinate to cut the abscissa at some point B which gives directly the position of the sample on the quality scale. For each of the six samples this procedure was followed and the resulting values read from the curve are shown in Table VIII.

By using the Comparator, measurements were made on the samples to ascertain the average thickness of the fibres and also to determine the distribution of fineness within each sample. Small bundles of fibres about two inches in length were cut away from the top at several places along its length. These bundles were then opened out on to a glass slide without any combing and the thicknesses of the fibres measured directly. In each case 250 fibres were taken and the distributions are shown in Table IX. Frequency curves were then plotted from these results and are shown in Figure 2 and Figure 3. The average thicknesses expressed in 1/1000 mm. were calculated from these figures and are shown in Table X.

Table VI

Sample	Dry Weight of Sample (1500 c.c.) in gms.	Dry Weight of 10 metres in gms. (Mean)
H	0·00592 0·00600	0·00397
E	0·00672 0·00707	0·00460
A	0·00736 0·00754	0·00497
T	0·00850 0·00841	0·00564
O	0·00929 0·00938	0·00622
N	0·01070 0·01060	0·00709

Table VII

Sample	Weight in mgms. of 10 metres at 18¼% regain $\left(\frac{W}{L}\right)$	$\log_{10} \frac{W}{L}$
H	4·695	0·6715
E	5·441	0·7357
A	5·880	0·7694
T	6·672	0·8243
O	7·356	0·8667
N	8·385	0·9235

Table VIII

Sample	Quality Number
H ...	70·75
E ...	64·75
A ...	64·25
T ...	60·45
O ...	58·8
N ...	56·9

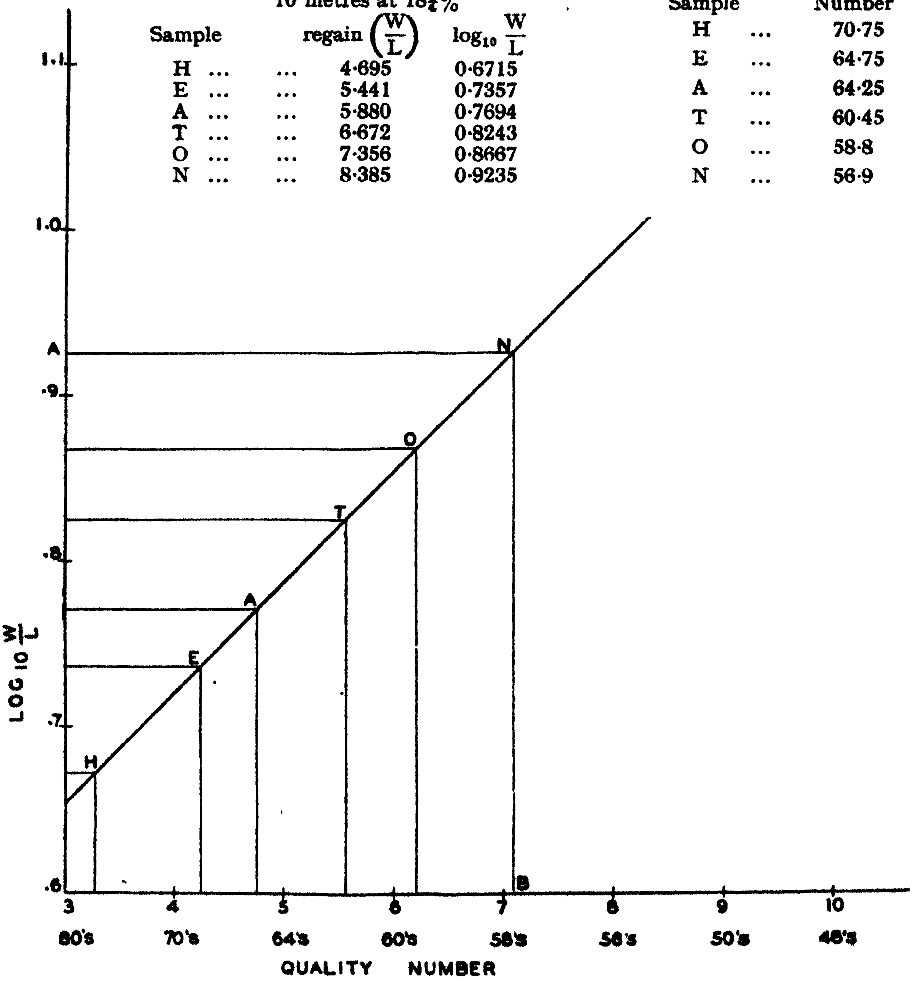

FIG. 1

Table IX

Thickness (1/1000 mm.)		Number of Fibres occurring				
	H	E	A	T	O	N
12 ...	2	2	—	—	—	2
14 ...	14	8	10	1	1	1
16 ...	55	33	22	7	11	9
18 ...	64	59	41	37	23	15
20 ...	49	53	69	35	22	14
22 ...	26	35	32	38	21	27
24 ...	18	31	33	46	37	24
26 ...	12	14	17	25	31	25
28 ...	6	10	6	20	26	44
30 ...	4	2	9	23	26	23
32 ...	—	1	6	7	15	23
34 ...	—	2	2	3	8	21
36 ...	—	—	1	4	8	13
38 ...	—	—	2	2	3	3
40 ...	—	—	—	1	7	3
42 ...	—	—	—	1	6	1
44 ...	—	—	—	—	3	1
46 ...	—	—	—	—	—	—
48 ...	—	—	—	—	2	—
50 ...	—	—	—	—	—	1
Total ...	250	250	250	250	250	250

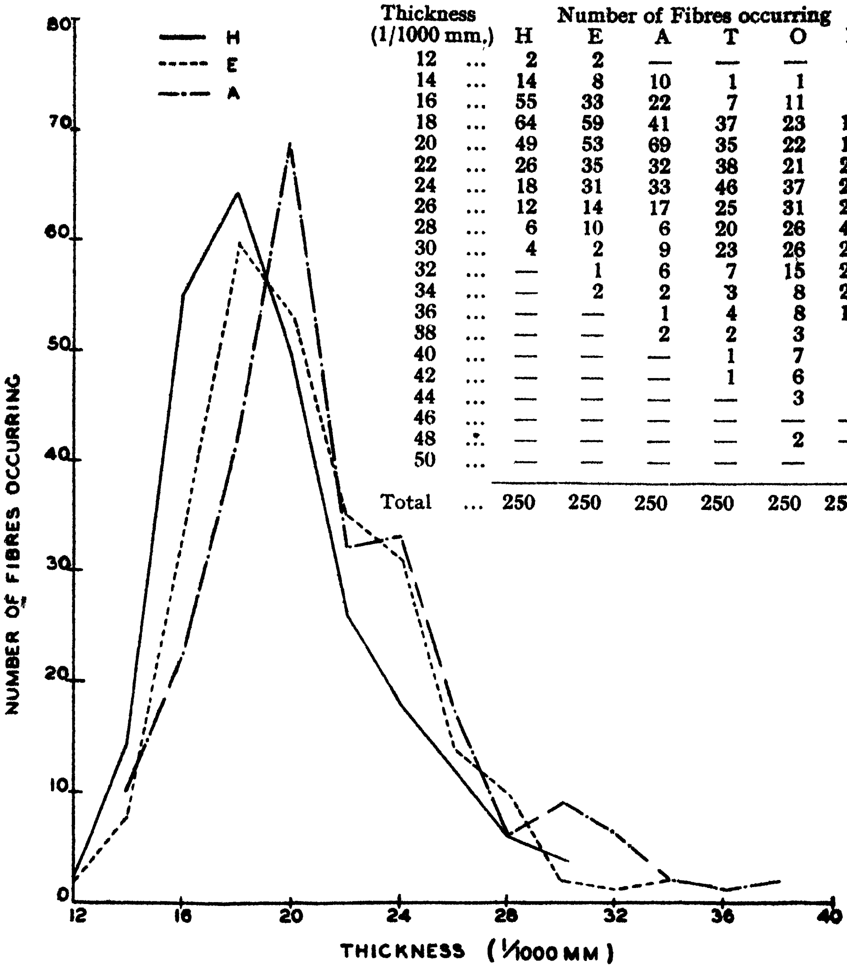

FIG. 2

Table X

Sample	Thickness 1/1000 mm.	Quality Corresponding
H	19·3	80's
E	20·4	70's
A	21·4	64's–70's
T	23·8	60's
O	26·5	58's
N	27·1	56's–58's

A COMPARISON OF COMMERCIAL, SCIENTIFIC, AND SENSORY STANDARDS

It is now possible to make, in Table XI, a comparison between the various methods of recording the degrees of difference in quality. In doing so it should be borne in mind,

That the Wool Federation Standard was arrived at after the most exhaustive commercial judgments by a number of highly skilled men.

That the Wool Industries Research Association's results are determined by fineness only and by eliminating judgment in all its forms.

That the Topmaker's figures are the average of two partial judgments—visual and tactile.

That only two of the eight groups could be regarded as skilled, one semi-skilled, and that the remaining five groups were men, women and children who had never seen or handled a wool top and that the results are the average of two sensory judgments.

That the judgments were, of necessity, determined by averaging the placings and calculating qualities therefrom whilst the physical measures were obtained direct from each individual sample, irrespective of its relation to the remaining samples.

That the statement is made in terms of trade qualities (80's, 70's, etc.) and that the decimals are the relative differences between those standards and ignore intermediates, *e.g.* 66's.

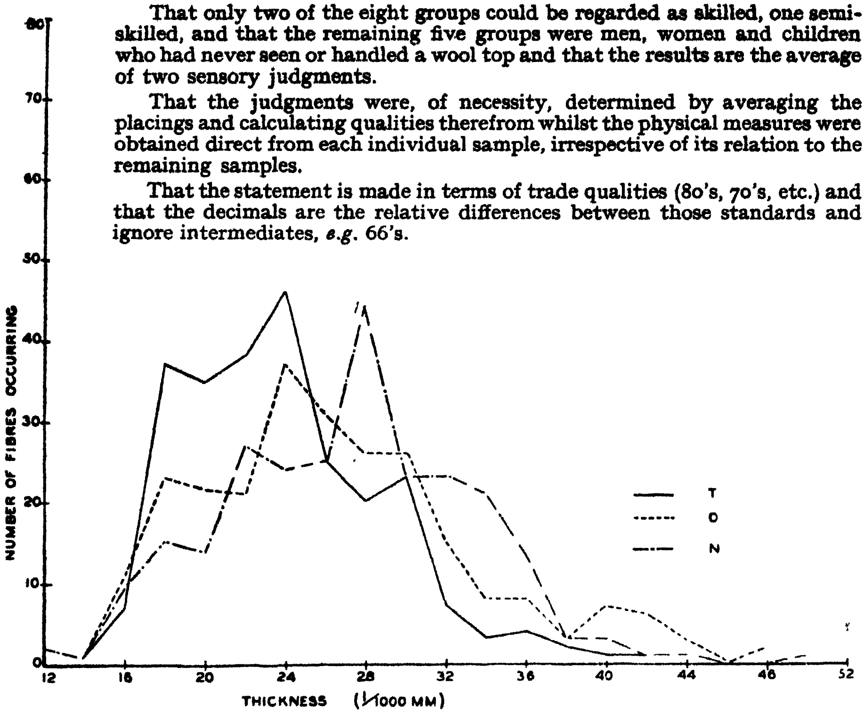

FIG. 3

Table XI

Identification Marks	H	E	A	T	O	N	Average Differences with Federation Standard
Federation Standard ...	80's	70's	64's	60's	58's	56's	—
Table VIII—log $\frac{W}{10L}$ ...	70·75	64·75	64·25	60·45	58·80	56·90	·48
Table X—Comparator ...	80's	70's	64/70's	60's	58's	56/58's	·17
Table II—Topmakers, av. sight and touch ...	70·88	70·08	60·76	60·20	56·91	56·04	·13
Table II—8 Groups, av. sight and touch ...	70·68	64·86	60·86	58·73	56·96	56·35	·21
Table XIV—Experimenter	70·51	64·91	64·29	58·77	56·97	56·15	·22
Table V—10 Selected touch	80's	64·95	60·90	60·15	58's	56's	·05

Without unduly stressing these differences in method and accepting the carefully selected samples as a criterion of quality, it is interesting to observe that the Topmakers only vary from this to the extent of about one-tenth of a quality, ·13, with the Comparator closely following at ·17 of a quality. The best results were obtained by the ten persons with "excellent" tactile sense, a mixed group of three girls, one woman, and six men in the trade (a wool-buyer, three topmakers, a spinner and a manufacturer), at ·05 of a quality.

It might be expected that groups, mainly quite unskilled, would be lower. But it is surely surprising that the variation should be so little from that of skilled men and amounting to only about one-fifth of a quality, ·21. With a poor visual, but a strong tactile judgment and with no experience of tops the experimenter is relatively high at ·22.

Of the logarithmic method much can be said in favour of its use in disclosing spinning properties or other factors which cannot be so accurately determined by any of the other methods. It seems significant, however, that the deviation is over double and nearly quadruple that of some of the others at ·48 of a quality.

In "Technical Terms in the Textile Trade", Vol. II (Midgley), under the heading of "Quality (Wools)", the following appears and is useful in connection with Fig. 4, which illustrates the chief features of Table XI. "The quality number given to combed wool fibre, although primarily based upon length and fineness, conveys some idea of its shrinking, felting, and spinning properties, its degree of lustre and also the class to which it belongs. . . . . . In the worsted industry the standard of 'counting' for yarns is based on the number of hanks per lb. the yarn may be spun out to, each hank being 560 yards in length."

INDIVIDUAL DIFFERENCES

The value of wool for a particular purpose is dependent upon variables which are primarily, but by no means entirely, based on diameter, softness, and length of fibre. This makes physical testing difficult and, in consequence, the decision is thrown on to personal judgment. Group judgments are not possible and opportunities for repeated judgments by one individual are not available. The responsibility rests with the individual who is called upon to make a decision alone and, often, quickly. This is particularly the case in wool-buying at the sales. It is important, therefore, that some indication of the probable errors of such persons be known. In Table XII the particulars mentioned in Table III are given for individuals.

The following conclusions may be drawn—

Sight and Touch Coefficients—In Table I, the uniformity of sight and touch judgments by groups is remarkable. In column (*a*) of Table III the average of 25 sight judgments compared with the average of 25 touch judgments in each group shows a final average of 1·00 for the 8 groups containing 200 units of judgment. In column (*b*) the comparison is made individually between sight and touch, the average of 5 persons being taken afterwards. The inference is in (*a*) therefore, that when the factors present are the basis of a natural (as distinct from a trained or technical) judgment a sufficient number of cases to cover the probable error will give high correlations between sight and touch. In (*b*) it is shown that, in the most highly skilled topmakers, the results compared with (*a*) are identical and that the other adult groups vary from the best in the following order—Technical Students; Women; Trade—Various; Art Student; and Men, with Girls and Boys last. Remembering that the girls have a very high score in "touch" it would appear that the cause of error is due to "sight". The more experience one has of wool-tops, the more does one realise the enormous difficulties there are in making visual judgments. A child cannot be expected to have this power and the results indicate this. The same factors are present in touch judgments, but cannot be recognised as such—the whole inner surface of one or both hands assists the mind in deciding on the simple question of softness. The analytical attitude of an adult male, in particular, tends to create its own difficulties which are recorded by the tests. Thus some girls of 12 years of age, of quite normal intelligence, are able to judge

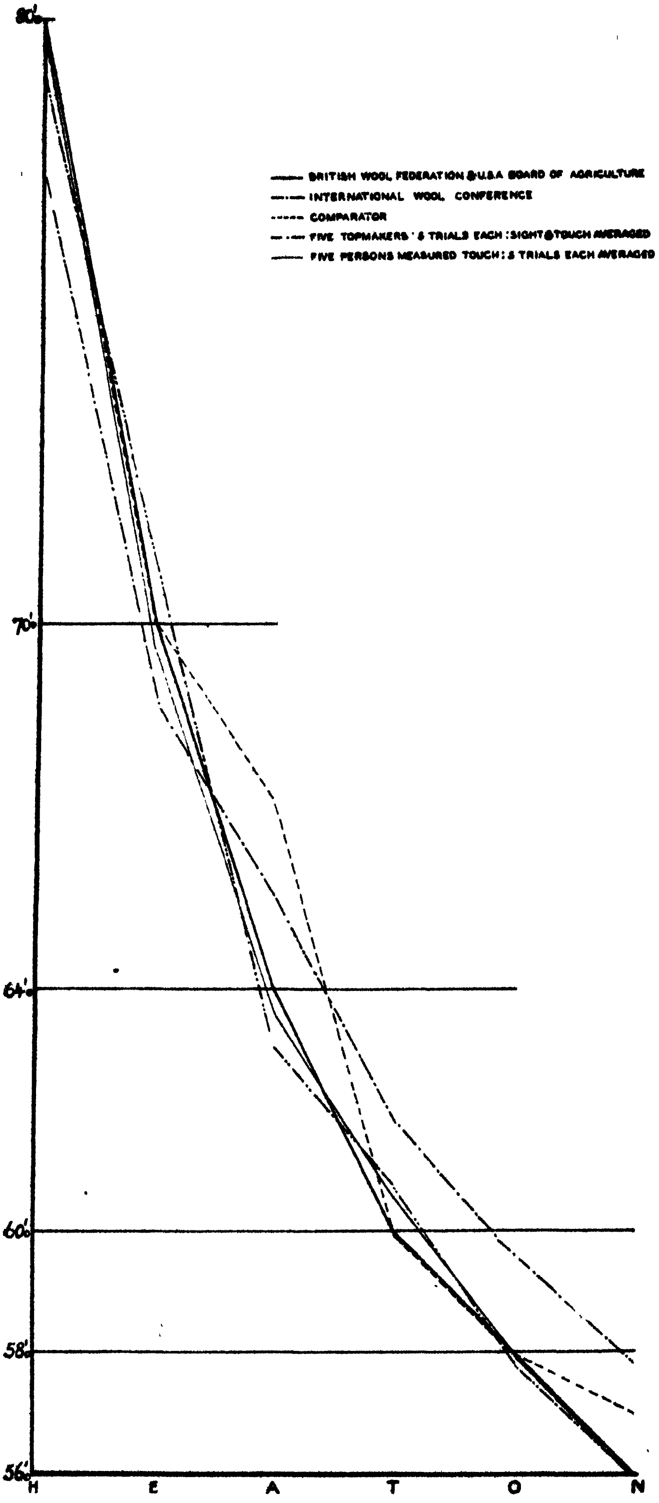
80's
70's
64's
60's
58's
56's
H
E
A
T
O
N
BRITISH WOOL FEDERATION & U.S.A BOARD OF AGRICULTURE
INTERNATIONAL WOOL CONFERENCE
COMPARATOR
FIVE TOPMAKERS' 5 TRIALS EACH : SIGHT & TOUCH AVERAGED
FIVE PERSONS MEASURED TOUCH : 5 TRIALS EACH AVERAGED

FIG. 4

Table XII

	SIGHT			TOUCH			COEFFICIENT OF CORRELATION	
	Errors	Inter-correlation	Standard	Errors	Inter-correlation	Standard	Errors	Sight and Touch
Topmakers—								
T1 Topmaker	10	·96	·99	4	·97	1·00	2	·99
T2 ,, ...	2	1·00	1·00	2	1·00	1·00	0	1·00
T3 ,, ...	0	1·00	1·00	6	1·00	1·00	0	1·00
T4 ,, ...	0	1·00	1·00	10	1·00	·99	2	·99
T5 ,, ...	0	1·00	1·00	4	1·00	1·00	0	1·00
Average	2	1·00	1·00	5	1·00	1·00	1	1·00
Trade—Various—								
S1 Manufacturer ...	18	·99	·89	4	·99	1·00	4	·89
S2 Wool Buyer ...	6	1·00	·99	2	1·00	1·00	2	·99
S3 Spinner	14	·95	·89	6	·99	1·00	4	·89
S4 Waste Merchant ...	8	·96	1·00	20	·73	1·00	0	1·00
S5 Topmaker	14	·99	·99	4	1·00	·99	2	·99
Average	12	·98	·95	7	·94	1·00	2	·96
Technical Students—								
C1 Spinner—Low tops ...	0	1·00	1·00	16	·92	·95	3	·95
C2 Asst. Combing Manr.	2	1·00	1·00	4	1·00	1·00	0	1·00
C3 Wool Grower and Buyer	4	·99	1·00	0	1·00	1·00	0	1·00
C4 Spinner	10	1·00	·99	18	·92	·99	4	·89
C5 Spinner	6	·99	1·00	4	·99	1·00	0	1·00
Average	4	1·00	1·00	9	·97	·99	1	·97
Arts and Crafts Students—								
A1 Woman—Art Teacher	16	·98	·99	2	1·00	1·00	2	·99
A2 Man—Illuminated Addresses... ...	8	·97	1·00	10	·97	·99	2	·99
A3 Woman—Hand Loom Teacher	8	·96	1·00	2	1·00	1·00	0	1·00
A4 Man—Imaginative Artist	44	·36	·64	12	·89	1·00	8	·53
A5 Man—Commercial Design	2	1·00	1·00	2	1·00	1·00	0	1·00
Average	16	·85	·93	6	·97	1·00	2	·92
Men—								
M1 Banker	16	·62	·99	6	·99	1·00	2	·99
M2 Journalist	18	·92	·99	16	·78	1·00	2	·99
M3 Electrician	22	·96	·89	16	·80	1·00	4	·89
M4 Water Diviner ...	26	·64	·82	12	·97	·99	6	·73
M5 Researcher	12	·93	1·00	14	·92	·99	4	·89
Average	19	·81	·94	13	·89	1·00	4	·90
Women—								
L1 Housewife	14	·90	·99	14	·82	·99	4	·89
L2 Graduate	8	·99	·99	0	1·00	1·00	2	1·00
L3 Medical	20	·88	·99	24	·73	·89	2	·99
L4 Housewife	14	·86	1·00	12	1·00	·99	2	·99
L5 Literary	14	·94	·99	18	·84	1·00	2	·99
Average	14	·91	·99	14	·88	·97	2	·97
Boys—								
Age School Manual *y. mo.*								
B1 12 0 VG FG	26	·58	·95	44	·53	·53	5	·82
B2 11 7 VG VG	10	·92	1·00	24	·73	·89	3	·95
B3 11 8 G G	10	·95	1·00	60	·08	—·65	16	—·65
B4 11 6 G G	4	·97	1·00	12	·90	1·00	0	1·00
B5 11 10 G G	12	·84	1·00	20	·94	·95	3	·95
Average	12	·85	·99	32	·64	·54	6	·61
Girls—								
G1 11 yrs. 9 mos. ...	14	·85	1·00	24	·64	·89	4	·89
G2 11 ,, 5 ,, ...	16	·99	·89	8	·99	·99	6	·73
G3 11 ,, 5 ,, ...	10	·94	1·00	0	1·00	1·00	4	·89
G4 11 ,, 9 ,, ...	18	·80	·95	0	1·00	1·00	3	·93
G5 11 ,, 4 ,, ...	36	·84	·53	2	1·00	1·00	6	·73
Average	19	·88	·87	7	·93	·98	5	·84

by touch as correctly as—or more so—than men of wide experience. This confirmed the idea, previously entertained, that a measure of tactile sense might be developed from these tests.

Topmakers—T1 handles the finest tops daily; T4 buys large quantities of greasy wool and sells tops; T2 and T3 have been known to the author for 15 years as outstanding judges, and they never fail; T5 a coming man of ability.

Trade—Various—This mixed group judges, as might be expected, on a lower level than the last group. S1 has a fine touch in his right hand and, by test, his left hand has one quality lower appreciation. S2, S3 and S5 are known, by previous tests, to have good touch. S4, over 60 years of age, has poor tactile appreciation and admits that he is at a disadvantage on this account.

Technical Students—C3, a young South African wool grower and buyer, worked at an average rate of 15 seconds per unit of judgment; C4, a spinner, made the error of reversing 58's and 56's qualities, and on touch his figures were erratic. In spite of this his agreement with the standard in both cases ·99, indicates that by a method of averaging, he might judge well, but, by buying on a single judgment he would probably be unreliable.

This group was asked, exceptionally, to place papers, on which were quality numbers, beside their "sight-arrangement" of the tops. The results are as follows—

Table XIII

	C1					C3					C4				
Quality	5 Trials					5 Trials					5 Trials				
80's	64	64	64	64	64	80	80	80	80	80	80	70	70	70	70
70's	60	60	60	60	60	70	70	70	70	70	70	64	64	64	64
64's	58	58	58	58	58	64	64	64	64	64	64	56	58	58	58
60's	56	56	56	56	56	60	64	60	60	60	58	58	56	56	56
58's	50	50	50	50	50	50	50	50	50	50	50	48	50	50	50
56's	50	48	48	48	48	48	48	48	48	48	50	50	50	50	48

C1 is a Swede who buys tops for spinners; his judgment of fineness involved only one error. It will be noted that his standard of quality is uniformly two qualities lower than what may be regarded as "typical" Bradford. C3, on the contrary, has an almost perfect appreciation of Botany qualities but underestimates the crossbreds, due, no doubt, to his experience of South African fine wools. C4, a young and probably inexperienced spinner, made more errors in grading than would appear from the details above, both 58's and 56's being graded as 50's. This emphasises the fact, which must always be borne in mind, that, in addition to stability of a person's judgment, he must appreciate a general level of quality before he can estimate the price and purpose factors with safety.

Art and Crafts Students—The reason for testing this group was to evaluate the differences between visual and tactile judgments trained within and without the wool trade.

It will be seen that A5, a commercial designer, doing work with fine detail, is equal to the best expert in the trade group, with only two errors each to sight and touch. He was greatly impressed with the test. The 80's quality "was much softer than the rest"; his final decisions were made on the back of his hand. He declared that his touch was progressively more sensitive. In three cases, A1, A3, both women, and A5, a man, there are only two errors in touch judgments. In the agreements between sight and touch also the co-efficient is either + 1·00 or + ·99, pointing to active co-ordination of these senses.

A4 came to the tests full of confidence; it will be seen that his appreciation of fineness is deplorable, his touch moderate, and his co-ordination of the two very bad. He is an "imaginative artist" with ideas of the bold, sweeping type. He would be useless in the wool trade and might be dangerous if his defects were not recognised.

Men and Women—The general level of persons without specific training by hand and eye is definitely lower, as illustrated by this group, than in the former groups. There is, indeed, only one outstanding case of merit. L2, a Southerner and a graduate, middle-aged, without apparently any outward evidence of unusual tactile sense, did the tests easily and without an error; her sight-judgments were also relatively good. Her co-ordination was perfect.

On the other hand a woman medical practitioner, L3, gave very low results at 20 sight and 24 touch errors.

M4, a water-diviner, wanted to know if his touch was unusual. The result was fair at twelve errors for touch with a "low" sight of 26 errors. A very serious motor smash crippled and almost blinded him, which may account for both results. He is still able, however, to prospect for water.

Boys and Girls—It would appear that in two groups, unknown to the writer and in the selection of which the Head Teachers concerned could have had no exact knowledge, there is a well-defined sex difference. Whilst visual appreciation is, in all cases, low, it is remarkable that three girls, under twelve years of age, score 0, 0 and 2 errors respectively on touch. The lowest errors of the boys were 12, 20 and 24; one reaching 60. The significance of this is already appreciated in industry when delicate handwork is required, but, so far as I am aware, no measurement of this kind has yet been suggested. A case of ill-balanced co-ordination is shown in B3, good at school work and handwork, with errors by sight 10 and by touch 60—a correlation between the two of —·65. But his sense of touch seems hopeless, as evidenced by the fact that he placed the clearly-defined best 80's quality in the 4th, 2nd, 5th, 6th and 1st places in different trials.

"Touch" and "Handwork" clearly need defining as to which is more sensory and that which is more muscular.

FLUCTUATIONS IN PERSONAL JUDGMENT

In previous experiments there are well-defined indications that the results from individuals of visual, tactile or full judgments remain fairly constant over a period of years, subject to minor disabilities such as ill health or anxiety. A decline in sensory appreciation is shown at an advancing age differing with each person and which is independent of sound abstract-judgment in which the senses are not primarily involved.

The average of any group of persons—trained or untrained—has shown repeatedly that a full judgment, in which sight and touch are necessary, is about midway between the independent judgments of these two senses. But, in the case of individuals, an unrecognised bias often due to specialisation or to inferior sensitivity of one of the senses, is present which attracts the individual to either the appearance or handle of a material. Thus opinions of two persons may vary, under the same conditions, with the utmost sincerity on the part of each.

It seems to be taken for granted that individual judgment remains constant from moment to moment and from day to day. Tests show this view to be incorrect, especially when associated with the senses. The extremes of these fluctuations appear, however, to be fairly consistent in each person, it is the aim of education and training to minimise the deviations and to form a correct standard of judgment.

In Table XIV the day-to-day fluctuations of the experimenter are shown. It will be observed that, whilst the touch judgments are excellent, those of sight on the three finest qualities are distinctly poor. Hence any full judgment would strongly tend to be influenced in the direction of handle.

Table XIV

EXPERIMENTER	SIGHT						Measure of Reliability	TOUCH						Measure of Reliability
	80's	70's	64's	60's	58's	56's		80's	70's	64's	60's	58's	56's	
1st Series	1·8	2·0	2·2	4·0	5·0	6·0	84	1·0	3·2	2·4	3·8	4·6	6·0	100
2nd ,, ...	1·4	2·6	2·0	4·0	5·0	6·0	92	1·2	1·8	3·4	3·8	4·8	6·0	96
3rd ,, ...	1·6	2·8	1·6	4·0	5·4	5·6	80	1·2	2·0	3·2	3·8	5·2	5·6	88
4th ,, ...	1·4	1·6	3·0	4·2	4·8	6·0	92	1·0	2·2	2·8	4·4	4·6	6·0	100
5th ,, ...	1·4	2·0	2·8	3·8	5·4	5·6	92	1·0	2·0	3·6	4·0	4·4	6·0	100
6th ,, ...	2·3	1·2	2·0	4·0	5·4	5·6	88	1·0	2·2	3·0	4·0	5·0	5·8	96
7th ,, ...	2·4	1·2	2·4	4·0	5·0	6·0	96	1·6	1·4	3·4	3·6	5·0	6·0	88
8th ,, ...	2·2	1·8	2·0	4·0	5·4	5·6	76	1·0	2·4	3·8	2·8	5·2	5·8	96
9th ,, ...	2·0	2·4	1·6	4·0	5·6	5·4	76	1·0	2·6	3·6	2·8	5·0	6·0	100
10th ,, ...	1·8	2·2	2·0	4·0	5·0	6·0	84	1·0	2·2	3·4	3·6	4·8	6·0	100
Average Place ...	1·88	1·98	2·16	4·80	5·20	5·78	86	1·10	2·20	3·26	3·66	4·86	5·92	96
Grade of Fineness and Softness	1	2	3	4	5	6	—	1	2	3	4	5	6	—
Percentage Standard ...	100	80	60	40	20	0	100	100	80	60	40	20	0	100
Experimenter Averages	82	80	77	40	16	5	77	98	76	55	47	23	1	97

The average group figures show clearly the bias of touch at 97 against 77 to sight. The average of sight and touch judgments of the groups in Table II and those in Table XIV are—

		80's	70's	64's	60's	58's	56's
Eight groups	...	93	79	57	45	19	7
Experimenter	...	90	78	66	44	20	3

Apart from the 64's quality the balance is about equal. The groups place sight at 63 and touch 52; the experimenter sight 77 and touch 55. Thus, the 64's is by general consent harder than it should be whilst its fineness is, by those better able to decide, a typical Bradford; yet it is here overestimated on fineness to the extent of nearly a full quality by the experimenter.

It may be interesting to note the fluctuations taking place during the course of one series of tests occupying perhaps a quarter of an hour. In addition the best and worst series of five judgments on sight and touch respectively are as follows—

SIGHT

		Good 4th Series, 6 Errors						Poor 6th Series, 22 Errors				
80's	...	2	1	1	1	2	...	3	2	3	3	3
70's	...	1	2	2	2	1	...	2	1	1	1	1
64's	...	3	3	3	3	3	...	1	3	2	2	2
60's	...	4	4	4	4	5	...	4	4	4	4	4
58's	...	5	5	5	5	4	...	6	5	5	6	5
56's	...	6	6	6	6	6	...	5	6	6	5	6

TOUCH

		Good 4th Series, 6 Errors						Poor 6th Series, 22 Errors				
80's	...	1	1	1	1	1	...	1	1	1	1	1
70's	...	3	2	2	2	2	...	2	3	3	2	2
64's	...	2	3	3	3	3	...	3	4	4	4	4
60's	...	5	4	4	5	4	...	4	2	2	3	3
58's	...	4	5	5	4	5	...	6	5	5	5	5
56's	...	6	6	6	6	6	...	5	6	6	6	6

At a glance it seems possible to prophesy what the full judgment of an individual would be. The value of touch as a corrective of sight is also apparent. When one remembers that in a full judgment the muscular action of drawing the top and of straining the fibres by sounding them with a finger as a strength test is added to that of tactile sense, the importance of handle will be appreciated.

In Table XV the weakness of sight judgment is shown. Visual errors range from 6 to 22 in five trials each at different dates, weeks apart; on touch there is a smaller variation, 3 to 14. The agreement with the trade standard on touch is almost perfect; but there is, by sight, an enormous range between ·73 and 1·00. The coefficients of correlation between sight and touch therefore, follow the tendency of visual judgments.

Table XV

	Sight			Touch			
Experimenter	Errors	Inter	Standard	Errors	Inter.	Standard	Coefficient
1st series	12	·93	1·00	14	·92	·99	·95
2nd ,,	16	·92	·99	8	·84	1·00	·99
3rd ,,	18	·94	·95	10	·89	1·00	·95
4th ,,	6	·99	1·00	6	·97	1·00	1·00
5th ,,	10	·88	1·00	10	·96	1·00	1·00
6th ,,	22	·96	·89	8	·94	1·00	·89
7th ,,	14	·99	·95	10	·97	·99	1·00
8th ,,	20	·89	·89	14	·96	·99	·73
9th ,,	22	·89	·73	12	·96	·99	·53
10th ,,	12	·94	·99	8	·96	1·00	·99
Average	15	·93	·94	10	·94	1·00	·90

COMPARISON OF TRAINED AND INEXPERIENCED JUDGMENTS OF WOOL TOPS

In Table XVI one series each of sight and touch judgments is given for a good, medium, and poor judges (*a*) who have had extensive practical experience and (*b*) who have never seen or handled a wool top at any time.

The remarkable consistency between the trained and untrained, T2 and A5, points to a basis of innate ability. L2 an ex-teacher, of middle age, has a more sensitive appreciation of both fineness and softness than has T1, an experienced topmaker with a high reputation in the trade for good judgment. S4, a topmaker and waste merchant, fails by reason of age, though he has had good experience. A4 does not appear to have any delicacy of judgment by sight, though his touch is fair.

THE PSYCHO-PHYSIOLOGICAL ASPECT OF TOUCH

The evidence here presented points clearly to the ability of individuals and groups to grade typical Bradford tops in their correct order of quality, regardless of experience, by sight and touch. This does not of course, imply that these abilities alone qualify a person to buy or sell wool in any form; there are many other important factors to be considered. But ability to discriminate, visually and tactually, is a significant basis on which these other factors may be built up. It may be well to examine the theoretical considerations with which visual and tactile sensations are associated.

Myers[8] says that "from the psychological standpoint, we have to remember that the occurrence of a sensation implies a change in the complex totality of consciousness, a change modified by past and present experiences, and modifying present and future experiences . . . The activity of the parts is inseparably bound up in the activity as a whole . . . Sensibility, in

Table XVI

	Quality	Sight					Errors	Touch					Errors
T2 Topmaker	80's	1	1	1	1	1		1	1	1	1	1	
	70's	3	2	2	2	2		2	2	2	2	2	
	64's	2	3	3	3	3		3	3	3	4	3	
	60's	4	4	4	4	4		4	4	4	3	4	
	58's	5	5	5	5	5		5	5	5	5	5	
	56's	6	6	6	6	6	2	6	6	6	6	6	2
A5 Art Student	80's	1	1	1	1	1		1	1	1	1	1	
	70's	2	2	2	2	2		2	2	2	2	2	
	64's	3	3	4	3	3		4	3	3	3	3	
	60's	4	4	3	4	4		3	4	4	4	4	
	58's	5	5	5	5	5		5	5	5	5	5	
	56's	6	6	6	6	6	2	6	6	6	6	6	2
T1 Topmaker	80's	2	2	3	1	2		1	1	1	1	1	
	70's	1	1	1	2	1		2	2	2	2	2	
	64's	3	3	2	3	3		3	4	3	4	3	
	60's	4	4	4	4	4		4	3	4	3	4	
	58's	5	5	5	5	5		5	5	5	5	5	
	56's	6	6	6	6	6	10	6	6	6	6	6	4
L2 Graduate Housewife	80's	1	1	1	1	1		1	1	1	1	1	
	70's	2	2	2	2	2		2	2	2	2	2	
	64's	3	3	3	3	3		3	3	3	3	3	
	60's	4	5	5	4	4		4	4	4	4	4	
	58's	5	6	6	5	5		5	5	5	5	5	
	56's	6	4	4	6	6	8	6	6	6	6	6	0
S4 Topmaker and Waste Merchant	80's	1	1	2	2	1		1	1	2	2	1	
	70's	3	2	1	1	2		2	3	1	1	4	
	64's	2	3	3	3	3		4	4	4	3	2	
	60's	4	4	4	4	4		5	2	5	4	3	
	58's	6	5	5	5	5		3	5	3	5	5	
	56's	5	6	6	6	6	8	6	6	6	6	6	20
A4 Art Student	80's	2	6	2	2	1		1	1	2	2	1	
	70's	1	5	3	4	4		2	2	1	1	2	
	64's	6	1	1	1	2		4	3	3	4	3	
	60's	4	3	5	5	5		3	4	5	3	4	
	58's	3	4	4	3	3		6	5	4	5	5	
	56's	5	2	6	6	6	44	5	6	6	6	6	12

fact, varies with the total mental state at the moment of determination and is affected by general or by local fatigue, by attention, practice, expectation, and interpretation."

In tactile acuity "the threshold varies according to the region, the extent, and the condition of the cutaneous area which is stimulated, and according to the rate of application of the stimulus." Stimulated by glass wool fibres and with a contact varying from 1/500 to 1/16 sq. mm. the following touch thresholds are recorded—tongue and nose, two grams; lips, 2·5 grams; finger tip and forehead, 3 grams; dorsal surface of finger, 5 grams; palm, arm and thigh, 7 grams; forearm, 8 grams; abdomen, 26 grams, and loins 48 grams.

Cotton wool is often used as a stimulus to determine tactile acuity, but, like glass wool fibre, it suffers from the fact that its quality is fairly constant and the pressure used is not defined. Combed wool in the form of tops can, however, be provided in almost any degree of softness and the stimulus is given by the person tested in the proportion best suited to himself and over the large area of both hands represented by an average threshold of 5 grams. The total mental state at the time of testing is largely determined by the emotional interest, created by the novelty of the situation which appeals to old and young alike.

The question arises whether the tests and methods here advocated throw any light upon the different thresholds of sensation on other parts of the body than the hands. The following are results obtained by the experimenter, the grading being the average of five trials.

Table XVII

	80's	70's	64's	60's	58's	56's	Errors	Inter.	Standard
Back of hands	2	3	4	1	5	6	28	·82	·82
Lips	1	2	4	3	6	5	22	·74	·89
Cheeks	1	3·5	3·5	2	5	6	34	·66	·89
Ears	2	3	1	4	5	6	42	·28	·89
Abdomen	4	3	1	2	5·5	5·5	38	·69	·41
Average place	2·20	2·84	3·24	2·36	4·92	5·44	33	·64	·90
Grading for softness	1	3	4	2	5	6	—	—	—
Experimenter's standard	1·10	2·20	3·26	3·66	4·86	5·92	10	·93	·99
Grading for softness	1	2	3	4	5	6	—	—	—
Stiffness standard	1·0	3·0	4·0	2·0	5·0	6·0	20	1·00	·89
Grading for softness	1	3	4	2	5	6	—	—	—
Experimenter exhausted, use of both hands	1·0	2·6	2·8	3·6	5·0	6·0	6	·98	1·00
Grading for softness	1	2	3	4	5	6	—	—	—

These figures are significant. The most striking is the fact that the average grading of 25 tests made on five parts of the body is exactly that recorded for "stiffness" which correlates with "softness" at ·89. Even if the use of these parts were practicable, the results would be worthless; the softest tops being stated as alternately 60's, 80's, 80's, 64's and 64's. The errors from trade standard average 33 with an intercorrelation of ·64 compared with the hand tests of 10 and ·93.

The explanation is, in the writer's opinion, that expressed in regard to difficulties of sight; the coarser long fibres and the shorter fine fibres in each top tend to confuse the issue when a small surface is stimulated. In practice about 1,000 sq. mm. are touched on the body compared with about 15,000 to 20,000 sq. mm. by the closing in of the hands on the material.

In a test made after an active day of gardening followed by tactile tests, there were only six errors—the consistency was ·98 and the grading absolute at 1·00. Despite the difficult conditions it would appear that the most delicate discriminations can be made—by individuals of known sensitivity—if the whole hand surfaces can be stimulated at their own discretion.

THE GRADING OF COLOURED YARNS BY THE SENSE OF TOUCH

If the assumption in the last paragraph be correct an indication of its value in commercial life should be useful. The experimenter purchased two sets of hanks "Botany All-Wool Mending" at Woolworth's early in 1933. One set (*a*) consisted of black, blue, grey, navy, light natural, white and tan. The other (*b*) were all grey—dark steel, light steel, dark blue grey, light blue grey mixture and two tones of dyed light slate. One of the dyed light slates was lost and this was replaced twelve months afterwards by another of exactly the same shade as the hank remaining.

Table XVIII gives the results of a series of ten judgments of five trials each for softness by touch alone on the six (*a*) Woolworth Mendings of different colours.

The group percentages show that, apart from the white and tan which are approximately equal, there are distinctive differences between the colours as a whole. The average measure of reliability at 78 is high for samples which

Table XVIII

Experimenter	Black	Blue Grey	Navy	Light Natural	White	Tan	Measure of Reliability	Inter-correlation
1st series	2·8	1·8	4·6	5·0	3·8	3·0	64	·25
2nd ,, ...	2·2	1·8	4·8	4·2	5·0	3·0	64	·41
3rd ,, ...	2·0	2·8	6·0	4·6	3·4	2·2	80	·64
4th ,, ...	2·2	1·8	5·2	5·8	3·0	3·0	80	·72
5th ,, ...	2·4	1·4	6·0	4·8	3·6	2·8	92	·79
6th ,, ...	2·2	2·0	6·0	5·0	2·4	3·4	80	·82
7th ,, ...	2·6	1·8	5·6	3·8	3·4	3·8	76	·34
8th ,, ...	2·0	2·2	5·8	3·6	2·6	4·8	76	·55
9th ,, ...	1·6	2·0	5·8	3·8	3·6	4·2	84	·63
10th ,, ...	3·0	1·0	5·4	4·0	3·4	4·2	88	·57
Average place ...	2·30	1·86	5·52	4·46	3·42	3·44	78	·57
Grade of softness ...	2	1	6	5	3	4	—	—
Group percentages ...	73	83	10	31	52	51	73	—

are assumed to be of the same wool quality, and though the inter-correlation is not strictly up to that required, it is within a practical measure of it.

Five experienced dyers were invited to grade the yarns. They hesitated and urged that scouring, bleaching, the use of acid colours or chrome colours and also softeners affected the softness. The time occupied in processing also had its influence, but under pressure they graded the samples, but with reservations, as follows—

	Black	Blue Grey	Navy	Light Natural	White	Tan	Measure of Reliability	Inter-correlation
Average place ...	5·8	3·0	4·2	2·0	4·0	2·4	76	·52
Grade by dyers ...	6	3	5	1	4	2	—	—
Experimenter's touch	2	1	6	5	3	4	—	—

The reliability of 76 and intercorrelation at ·52 are a little below the requirements. The dyer's grading is in disagreement with the experimenter's touch at —·26

Table XIX follows for Woolworth's Mendings (*b*) Greys only.

Table XIX

Experimenter	Light Slate (*a*)	Light Slate (*b*)	Light Blue Grey Mixture	Light Steel	Dark Blue Grey	Dark Steel	Measure of Reliability	Inter-correlation
1st series ...	1·4	6·0	2·2	4·4	3·2	3·8	92	·87
2nd ,, ...	1·0	6·0	2·0	4·6	3·8	3·6	100	·99
3rd ,, ...	1·4	6·0	2·2	4·2	4·0	3·2	92	·82
4th ,, ...	1·4	6·0	2·0	4·2	4·0	3·4	92	·82
5th ,, ...	1·8	6·0	1·8	5·0	3·6	2·8	84	·89
6th ,, ...	1·4	6·0	2·4	5·0	3·8	2·4	92	·92
7th ,, ...	1·4	6·0	2·0	4·8	4·2	2·6	92	·96
8th ,, ...	1·8	6·0	1·6	4·2	3·4	4·0	84	·77
9th ,, ...	1·4	6·0	1·8	4·8	4·0	3·0	92	·92
10th ,, ...	1·4	6·0	1·8	4·4	3·8	3·6	92	·82
Average place ...	1·44	6·00	1·98	4·56	3·78	3·24	91	·88
Grade of softness	1	6	2	5	4	3	—	—
Group percentages	91	00	80	29	45	55	91	—

Although practical men would expect a group of six greys to be less distinguishable by touch than six colours, it will be seen that the measure of reliability, 91, and the intercorrelation ·88, are exceedingly high. There is no ambiguity in the relative softness of each sample. Nor is there any serious lapse, such as occurred in the coloured range, in the consistency of repeated judgments at each separate trial.

Though the light slates (*a*) and (*b*) were of the same shade they take respectively the first and sixth positions. This is probably due to the rise in price which took place between the purchase of the five samples in which (*a*) was included and the replacing of the sixth (*b*). In any case the difference is definitely detected by the sense of touch.

The dyers graded as follows—

	Light Slate (*a*)	Light Slate (*b*)	Light Blue Grey Mixture	Light Steel	Dark Blue Grey	Dark Steel	Measure of Reliability	Inter-correlation
Average place	2·2	3·6	2·2	3·8	3·8	5·4	64	·34
Grade by dyers	1·5	3	1·5	4·5	4·5	6	—	—
Experimenter's touch	1	6	2	5	4	3	—	—

The reliability is too low to be of any value, as might be anticipated in the technical factors involved in dyeing; so that the correlation with the experimenter's touch at ·53 is likewise worthless.

THE OPERATIONS OF CHANCE

In experiments of the character already detailed the question arises as to how far chance may operate on one or all the judgments of an individual. Theoretically, purely chance selections should result in zero correlations. If a sufficiently large number of cases were recorded this would no doubt apply. But in practice time is not available for an indefinite number of experiments. The experimenter took the six samples of grey yarns, mixed them thoroughly and then by chance selection recorded the results on the same lines as those of judgment selections. Table XX gives the details of these.

Table XX

CHANCE—GREY YARNS

	Light Slate (*a*)	Light Slate (*b*)	Light Blue Grey Mixture	Light Steel	Dark Blue Grey	Dark Steel	Measure of Reliability	Inter-correlation	Standard
1st series	3·0	3·4	4·4	5·4	2·6	2·2	64	·42	·00
2nd ,,	2·4	5·2	4·2	3·6	1·8	3·8	68	·42	·00
3rd ,,	2·6	3·8	4·2	3·2	3·4	3·8	32	·00	·26
4th ,,	3·4	4·8	3·8	2·8	1·6	4·6	63	·29	·00
5th ,,	3·6	3·8	2·8	4·0	4·0	2·8	24	—·05	·53
6th ,,	2·4	1·0	5·2	4·0	5·0	3·4	84	·77	·00
7th ,,	2·8	4·4	4·8	2·4	3·4	3·2	28	·26	·29
8th ,,	5·0	3·4	3·4	4·0	1·8	3·4	64	·28	·00
9th ,,	4·0	4·4	5·4	1·8	3·0	2·4	72	·52	—·26
10th ,,	2·4	4·2	3·2	3·0	5·6	2·6	64	·40	·53
Average	3·16	3·84	4·14	3·42	3·22	3·22	56	·33	·13
"Chance" grading	1	5	6	4	2·5	2·5	—	—	—
Group percentage	57	43	37	51	56	56	20	—	—

On average, the intercorrelations and the agreement with the standard are both well below the lowest limit of the probable error, *viz.* ·60. In detail, the sixth series gives a very high consistency of ·77 which is at zero with the standard. The fifth series, on the other hand, shows an intercorrelation of —·05 with a fairly high agreement with the standard at ·53. It would not be anticipated that the following gradings could result from a purely chance selection.

	6th Series Trials					5th Series Trials				
Light slate (*a*)	2	2	4	2	2	5	2	2	3	6
,, ,, (*b*)	1	1	1	1	1	4	3	3	5	4
Light blue grey	4	6	6	4	6	1	5	1	2	5
Light steel	5	4	3	3	5	6	1	5	6	2
Dark blue grey	6	5	5	5	4	3	6	6	4	1
Dark steel	3	3	2	6	3	2	4	4	1	3

If, therefore, the differences between samples are subtle and it is desired to find the relative differences between them, it is essential that about 50 tests should be made. When a standard is known and the differences are recognisable by trained and untrained people alike in five trials each, it seems probable that this number is ample to test the tactile ability of an individual. Should the differences be minute and difficult to appreciate a second or third series might with advantage be tried on different days. The "probable error" would seem, therefore, to be of much greater value than business men attach to its use.

GENERAL CONCLUSIONS

From the foregoing, the author suggests the following general conclusions—

The *Commercial Judgment of Tops* constitutes one of the most exacting tests of the "Fundamentals of Sound Judgment" as detailed in "Personal Judgment in Industry and Commerce."[9] To select and place a forward contract, on unknown tops, in a rapidly fluctuating market, requires the presence of nearly all the numerous factors there stated. The only possible ultimate measure is the final result of the deal. The judgments of experienced persons—if not weakened by age or other disability—are more likely to be disturbed by complexity arising from the material, than from fluctuations arising from psychological causes.

The *Visual Judgment of Tops* depends for its accuracy upon the correctness of each individual's judgment of his own draw. Good North light and appropriate environment are beneficial. Most of the general factors of sound judgment are still present. Such visual tests of ability to define fineness and quality are only practicable in so far as they are administered under expert control and for use within the industry for selection of candidates for the raw material sections of the trade.

There are several accurate methods available for assessing the fineness of fibres and other factors associated with the sense of sight, but there is no corresponding means of measuring the factors connected with the sense of touch. In consequence the tendency in commercial transactions and in scientific testing is to stress the visual—the appearance rather than the handle.

The *Tactile Judgment of Tops* as illustrated in these tests is of universal application. With normal external conditions of temperature and environment any person would be able to give to any other person, children included, the very simple tests necessary for tactile measurement, with the certainty that reliable results would follow.

The evidence it seems to me is entirely in favour of the method presented providing a simple measure of tactile sense at the time of the testing. Natural ability, aided by practice, or depressed by advancing age or other causes appears to be correctly recorded, without the confusion of results by bodily temperature, light touch or pressure senses together with impulses from the muscles. The human being becomes the measuring instrument—often a very delicate one—and a beginning is made in evolving a method of defining softness and handle comparable with that given to fineness. No instrument is required and the cost of a 20 to 30-minute test for a person's sensitivity of hand-touch at the present cost of the tops, would be about one halfpenny.

Arbitration—Without in any way diminishing the value of the microscope, the Comparator, or other scientific instrument, it would seem possible to use skilled judgment for delicate problems requiring arbitration. If, for example, a given sample of tops were in dispute, one person should select two different samples slightly better and two slightly worse, with one approximately the same as the sample in question. He would give secret marks to these—six samples in all.

The two chief persons concerned on either side, together with one selected by each, and one other agreed upon by both as an impartial judge, should each grade the samples from 1 to 6 according to agreed instructions. The judgments should be made in the same room by each person alone with the experimenter and if possible about the same time to secure uniform conditions. The instructions should be written and no word concerning the tests should be spoken. The calculations should be carried out as previously described. In this way the very subtle influence of suggestion would be avoided; the results would be impartial; both sides may decide for or against themselves and the results are obtained from practical men on a commercial basis. For judgments of fineness of fibre, small boards may be found useful. Draws can then be placed in different positions of light for direct comparison. On touch it is found that a change of hands is helpful.

Judgment and Science

Some confusion exists concerning the relative advantages of the judgment of the "practical man" and the measured results obtained by scientific methods; between the two viewpoints the "Spirit of Science" should not be overlooked, as this may be applied, as previously shown, to judgment.

The human mind is the only instrument capable of using the experience of the past, to decide in the present, that which is to be used in the future. It is able to co-ordinate and decide quickly when factors under consideration are numerous, complex, irregular, and fluctuating; in these respects "mind-sense" judgments are unique. The disadvantages are that individuals vary very considerably in their judgments made from the same set of factors; that each person fluctuates in his ideas from minute to minute and day to day, though within well-defined personal limits, determined by experience, knowledge, and temperament.

Science, mainly by the use of instruments and optical apparatus, eliminates these fluctuations and differences, reducing all to one common measure of accuracy; it seeks to dispense with the vagaries of personal judgment. In doing so, it must measure each separate factor and co-ordinate many factors by appropriate statistical methods. Valuable as the exact knowledge of each factor may be, difficulties arise in the assessment of the relative values to be placed on widely divergent factors, which judgment automatically provides by means of experience and memory.

If the "Spirit of Science" be accepted by both practical men and scientists, the points enumerated in "Fundamentals of Sound Judgment" will be considered important in their effect on education and systematic training and the measurements resulting from science will be gladly accepted as a most valuable asset under the headings of "knowledge" and "impartiality". There is no conflict between the two points of view; they automatically fit and vary in their relative values according to the complexity of the factors and the time at disposal.

The following are suggested as

Fundamental Factors in Sound Judgment

(1) Capacity—Natural and acquired for dealing with a new situation involving persons and materials.

(2) Specific Ability—To concentrate on and co-ordinate numerous, complex, irregular, and fluctuating factors quickly in one decision.

(3) Knowledge—Awareness of the existence of all factors of a problem with adequate knowledge of the essential ones; willingness to supplement one's own information with that from trustworthy sources; confidence.

(4) Intuition—Arising out of sub-conscious memory in which is stored a much wider experience than that covered by the actual facts under review; ability to "sense" a situation; sustained emotional interest; imagination; faith.

(5) Impartiality—Ability to weigh evidence; to control by will temperamental tendencies; to resist suggestion; and to correct the bias caused by specialisation.

(6) Stability—Good health, with freedom from anxiety and other depressing emotions which tend to induce temporary, but erratic, fluctuations.

These principles are suggested as a working basis by which the accuracy of a particular judgment by a certain person may be assessed. While all the factors must of necessity overlap, it seems possible, in practice, to recognise each in important commercial decisions.

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22—STUDIES IN THE SAMPLING OF YARNS FOR THE DETERMINATION OF STRENGTH PROPERTY

PART I—FREQUENCY CURVES OF STRENGTH TESTS BY SINGLE THREAD, LEA AND BALLISTIC METHODS OF TESTING

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SUMMARY

In the present series the applicability of the general "theory of errors" to experimental results of tensile strength tests on yarn is explained. In Part I the fundamental statistical problem of determining the general forms of frequency distributions for strength test series obtained by the single thread, lea, and ballistic methods of testing is discussed. It is shown that in the individuals of such populations there exists an interdependence or correlation in the attributes of the strength measurement, as between strength and count, which causes heterogeneity. As a consequence of this, the series fail to fulfil the conditions of the general law. Count correction is therefore effected in the test results to obtain more efficient statistics representable in mathematical form. Attention is drawn to an indiscriminate use of the *normal law* and the extent of variation from normal theory that may be expected in sampling, due to the fact that the variability is the resultant of contributory causes tending to produce asymmetrical frequency distributions. The conclusion derived is that the frequency forms of single thread tests are moderately skew and can be described by the Type I equation from the Pearsonian system of curves and *normal* in one case. The lea test series demonstrate the symmetry proper to the normal law of error, while ballistic test distributions are extremely asymmetrical and are represented by Type III, V, and VI equations from the same system of curves.

In Part II* the analysis of the variability of the material will be described. A warning is given against the practice of casually expressing significance of estimates involving probability in terms of probable errors of results. To make the theory of errors applicable to the experimental data it is proposed to effect the requisite extension in the theory as suggested by "Student" and Fisher in their work on the analysis of the variance of sub-samples. The manner of experimental sampling suggested is a sort of systematic random selection of test specimens, the specimens being drawn from ten test bobbins to give reliable estimates made up of 50 lea, single thread, and ballistic count-strength measurements.

INTRODUCTION

In many textile problems it is necessary to obtain strength measurements of yarns. But to arrive at a correct judgment of the strength property it is indispensable to have definite knowledge of the best method of carrying out the experimental sampling and of the number of tests necessary to form a reliable estimate of the property measured. The object of this paper is, therefore, to investigate the theory of sampling as applied to yarns tested by the single thread, lea, and ballistic methods of strength testing.

Yarn-strength test results are characterised by complex variability, so that statistical analysis of the results becomes requisite in order to deduce a correct interpretation of the values of observations. In general, statistical processes are based on the theory of probability. The most generally used law, derived from this theory, is sometimes known as the *normal law of error*. But in spite of the great utility of this law, particular care is necessary in applying it to the results of yarn strength tests.

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* To be published in January 1935—*Editor*.

In Part I of the present series is shown the extent to which departure may be experienced from the *normal law* in sampling. It is pointed out that the values of observations not only depend on the distribution of accidental influences—errors in the true sense of the word—but are also subject to persisting influences. Therefore the variability is the resultant of a number of contributory causes tending to produce asymmetrical frequency distribution. Recognising this difficulty, in Part II of the series the methods of determining trustworthy estimates of means within assigned limits will be examined, and the number of tests constituting a satisfactory sample, representing the bulk from which it is drawn is indicated.

EXPERIMENTAL

To supply the necessary data for such an inquiry 80,000 single-thread tests, 2,300 lea tests, and 2,200 ballistic tests were made on yarns spun from different varieties of cotton. For the purpose of single-thread testing, 10 lb. of lint of each of the standard Indian cottons—Surat 1027 A.L.F., Punjab-American 4F, and Dharwar were taken and the former two spun into 20's and Dharwar into 20's and 40's carded yarns under conditions of spinning described in "Technological Reports on Standard Indian Cottons, 1930".* All the testing was done on a Goodbrand single-thread tester to give a constant rate of loading (12 inches per minute). The length of the test specimen between the grips was kept 12 inches. Without allowing the twist to run out by manipulating the grips alternately and removing the broken portion of the test specimen, successive tests without a break in the continuity of the yarn along its entire length were obtained till the bobbin was completely exhausted. Further, it being known that the variability in the breaking load of yarn is affected in a measure inversely by difference in count values, with a view to isolate the effect of count variation on breaking-load and obtain a definite measure of this factor, the portions of yarn actually broken in a single-thread test were weighed on a torsion balance to determine the count value of 15 successive specimens in the case of Surat 20's and 25 for the yarns spun from Punjab-American and Dharwar cottons. It was found that each bobbin of 20's yarn contributed 4,000 tests, so that the aggregate number of tests for the five bobbins of 20's yarn for each of the cottons amounted to 20,000 test results, while in the case of 40's yarn spun from Dharwar cotton, 6,675 tests from the first two bobbins and 6,650 tests from the third bobbin were obtained to give the same total number of tests.

To provide data for lea and ballistic tests, two other varieties of Indian cotton, Berar and Dharwar, were spun into 10's and 20's yarns, and Kampala, a variety of Uganda cotton, into 40's yarn. These yarns were spun on 20 spindles (tape driven) following the procedure stated in the preceding paragraph. Lea tests were made on the Goodbrand lea tester, maximum load 150 lb., electrically driven at a constant rate of loading 12 inches per minute. The ballistic tests were made on half-leas with Goodbrand's ballistic testing machine, placing the half-leas with a hitch knot at each cross bar. The actual count of each previously-used lea in the lea test and half-lea in the ballistic test was determined by weighing it on an Avery yarn balance. Lea and ballistic tests of the order of 800, 700, and 800 on 10's, 20's, and 40's yarns respectively were obtained for statistical analysis. Each bobbin was marked with the spindle number denoting the spindle on which it was spun. Spinnings on 20 spindles were kept separate into two lots, each lot representing the production of 1 to 10 and 11 to 20 spindles. A set of 100 bobbins of each lot of 10's Berars, 50 bobbins of Dharwar 20's, and 30 bobbins of Kampala 40's were obtained as test material. The bobbins of each lot were well intermingled and 70, 30, and 20 bobbins were taken out at random to give the required number of lea tests on each kind of yarn. The residual bobbins were then used for obtaining ballistic tests. The object of drawing test material in this manner was to obtain test results representing the spinning product in which the effect of roving differences was equally distributed and the spindle effect isolated. All the testing was carried out between 67 and 72% relative humidity.

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* Published by the Indian Central Cotton Committee.

Statistical Method Employed

By the adoption of the three methods of testing, four series of observations of single-thread, and three each for lea and ballistic testing were obtained. In order to comprehend the characteristics of these variable series, frequency distributions are given in Tables II and VI. The first question that presents itself is to what extent these experimental series may be regarded as representing the behaviour of a variety or the product of a spinning test. In order to derive information of this nature, the first step in the analysis consists in deriving some mathematical form representing these observed frequency distributions which will fulfil the conditions of a general law. The statistical system used for this purpose, is the one described by Karl Pearson[1] and familiarly known to statisticians as the "P,χ^2 test for goodness of fit". In the case of the single-thread strength series, since the P,χ^2 test proves that there is a lack of correspondence between observation and theory due to heterogeneity in the frequency-distribution series, analysis is carried further with a view to ascertaining the cause of the heterogeneity and to deriving a series wherein the influence of the variate causing the heterogeneity is modified to give the units grouped together in the tested material a homogeneous character.

In the discussion that follows the question as to whether the distributions conform to the normal frequency distribution is first investigated and, in the instance where a departure from normality is proved, the type of curve from the Pearsonian scheme[2] that would best describe the given frequency distribution is decided upon.

DISCUSSION OF SINGLE-THREAD STRENGTH RESULTS

It is evident from Table I that for Surat 20's results, β_1 is almost equal to zero. The difference in the value of β_2 from the limit three is about four times the probable error of β_2. Skewness is less than the probable error and the criterion κ_2 is also nearly zero. From this it would be valid to maintain that the differences between constants are not significant. The resolution of the statistical data signifies that the given frequency distribution can be described by a normal frequency-distribution curve having for its equation

$$y = 5200{\cdot}656\, e^{-x^2/4{\cdot}70756}$$

Table I

Statistical Constants and their Probable Errors (Single-thread Test Series)

Statistical Constants	Surat 20's	Punjab-American 20's	Dharwar 20's	Dharwar 40's
Total number of observations ...	20,000	20,000	20,000	20,000
Mean value (oz.)	10·999	9·895	13·353	6·212
Mode	11·008	9·746	13·233	6·262
Moment coefficient β_1	0·000	0·030	0·038	0·013
Probable error of β_1 from moments	0·000	0·003	0·006	0·000
Moment coefficient β_2	2·914	3·020	3·622	3·312
Probable error of β_2	0·021	0·026	0·066	0·039
Skewness	−0·005	0·088	0·073	−0·047
Critical function $\varkappa_1$	−0·172	−0·051	1·129	0·586
Probable error of $\varkappa_1$	0·042	0·050	0·128	0·078
Critical function $\varkappa_2$	0·004	−0·448	0·026	0·016
Probable error of $\varkappa_2$	0·000	—	0·004	0·002
Standard deviation	1·534	1·683	1·651	1·050
Coefficient of variation	13·94	17·01	12·37	16·90

Testing for "Goodness of Fit" the value of χ^2 is of the magnitude 57·952 which gives for the probability P, which is a function of χ, the value 0·000029. The curve, while it gives broadly some of the features of the experimental distribution, by no means yields a satisfactory measure of agreement. The numerical values determined for the theoretical frequency in relation to normal equation are set out in Table II.

Table II

Observed and Theoretical Frequency Distributions (Single-thread Test Series)

Values	SURAT 20's		PUNJAB-AMERICAN 20's			DHARWAR 20's		DHARWAR 40's	
	Observed Frequency	Theoretical Frequency Normal Curve	Observed Frequency	Theoretical Frequency Type I	Theoretical Frequency Type III	Observed Frequency	Theoretical Frequency Type IV	Observed Frequency	Theoretical Frequency Type IV
3·5	—	—	—	—	—	—	—	254	245·60
4·0	—	—	—	—	—	—	—	403	411·23
4·5	—	—	—	—	—	—	—	915	935·90
5·0	—	—	—	—	—	—	—	1823	1825·41
5·5	—	—	73	77·52	81·16	—	—	3119	2941·95
6·0	21	18·70	132	132·37	133·56	—	—	3805	3792·26
6·5	43	35·23	300	286·74	285·77	—	—	3423	3813·83
7·0	79	86·89	551	541·15	537·47	—	—	3205	2955·92
7·5	157	192·71	862	901·42	895·56	—	—	1710	1771·69
8·0	410	384·36	1422	1337·58	1332·08	—	—	821	836·03
8·5	683	689·35	1763	1781·19	1778·56	41	57·83	522	462·73
9·0	1148	1111·75	2103	2143·06	2138·42	55	65·70	—	—
9·5	1594	1612·35	2215	2344·50	2350·39	118	134·28	—	—
10·0	2209	2102·70	2523	2343·78	2350·49	350	262·31	—	—
10·5	2423	2465·80	2084	2150·57	2155·37	558	482·38	—	—
11·0	2723	2600·33	1910	1819·15	1820·43	877	822·44	—	—
11·5	2243	2465·80	1309	1423·53	1421·27	1250	1281·06	—	—
12·0	2142	2102·70	1061	1033·77	1029·85	1651	1800·28	—	—
12·5	1551	1612·35	672	698·93	694·93	2256	2261·99	—	—
13·0	1181	1111·75	463	440·98	438·07	2618	2530·33	—	—
13·5	645	689·35	253	260·18	258·74	2150	2521·27	—	—
14·0	395	384·36	155	143·85	143·59	2213	2250·25	—	—
14·5	192	192·71	149	139·42	142·19	2084	1815·96	—	—
15·0	161	140·81	—	—	—	1500	1341·26	—	—
15·5	—	—	—	—	—	881	918·98	—	—
16·0	—	—	—	—	—	589	592·13	—	—
16·5	—	—	—	—	—	340	363·48	—	—
17·0	—	—	—	—	—	238	215·06	—	—
17·5	—	—	—	—	—	104	123·90	—	—
18·0	—	—	—	—	—	55	70·10	—	—
18·5	—	—	—	—	—	72	88·23	—	—

For Punjab-American 20's results, the difference in the value of β_1 from the limit zero is significant, but the difference in the value of β_2 from the limit three is less than the probable error. On the other hand, passing on to other constants—*e.g.* skewness and the criteria $\varkappa_1$ and $\varkappa_2$—it will be observed that they fully determine the non-symmetrical nature of the curve, because the skewness factor is 15 times the probable error. The P.E. of criterion $\varkappa_1$ is as large as the criterion itself and criterion $\varkappa_2$ is significantly negative. The high value of the P.E. of criterion $\varkappa_1$ indicates proximity to a critical limit and relative to $\varkappa_2$ the solution may either fall within the area given by the curve for an equation of Type I or Type III—

$$\text{Type I} \quad \ldots \quad y=4739{\cdot}818\left(1+\frac{x}{13{\cdot}66526}\right)^{51{\cdot}17285}\left(1-\frac{x}{48{\cdot}5931}\right)^{181{\cdot}96865}$$

$$\text{Type III} \quad \ldots \quad y=4753{\cdot}494\left(1+\frac{x}{19{\cdot}25974}\right)^{131{\cdot}8853} e^{-6{\cdot}847719.x}$$

The value of χ^2 when Type I and Type III equations are fitted to the observed distributions is of the magnitude 50·289 and 50·514 and the probability P is of the order 0·00013. It appears that, comparatively, Type I equation has the nearest approach in point of agreement to the observed series, but fails to provide an adequate description of the observed frequency. The theoretical frequency distributions with regard to the equations explained above are given in Table II.

Analysis of statistical data, for Dharwar 20's results, reveals some marked traits. The difference in the value of β_2 from the limit three is about 27 times the P.E. The skewness being about 12·5 times the P.E., these deductions point towards a sensible change in the shape of the curve from normality. Being an asymmetrical curve, it remains to examine by which type of curve from the Pearsonian scheme it could be represented. The answer to the question could be deduced from the evidence, that the value of the criterion $\varkappa_2$ being $0{\cdot}02573 \pm 0{\cdot}00415$ (positive and greater than zero but less than unity) is significant and a Type IV curve should be used to represent the given distribution—

$$\text{Type IV} \quad \ldots \quad y=4376{\cdot}672\left(1+\frac{x^2}{33{\cdot}81326}\right)^{-7{\cdot}86503} e^{2{\cdot}281045 \tan^{-1} x/5{\cdot}814935}$$

Comparison of the actual and theoretical frequencies when fitting an equation of Type IV brings the value of χ^2 as 198·229 and P as zero, indicating that it is impossible to secure any degree of correspondence between observation and theory.

The theoretical frequency distribution determined from the values of observations for the equation are given in Table II and graphically represented in Fig. 1.

Dharwar 40's results indicate that the difference in the limiting β_2 from three is about 13·5 times the P.E. So also the skewness factor is eight times the P.E., and as the criterion $\varkappa_2$ is of the magnitude $0{\cdot}0162 \pm 0{\cdot}0017$, they prove that the observed distribution is a characteristic skew frequency distribution. It lends itself to the same conclusions as the Dharwar 20's tests

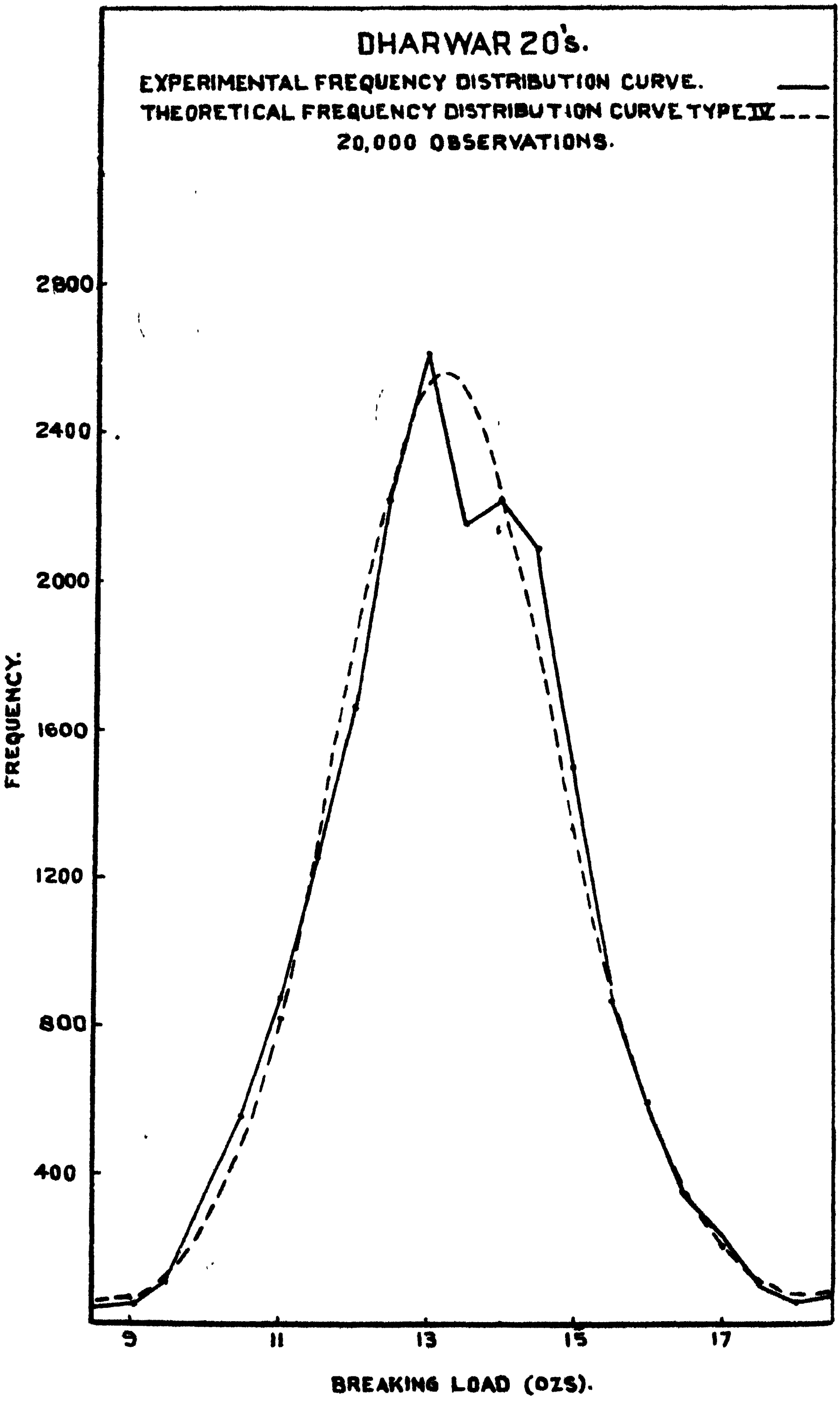
DHARWAR 20's.
EXPERIMENTAL FREQUENCY DISTRIBUTION CURVE. ——
THEORETICAL FREQUENCY DISTRIBUTION CURVE TYPE IV - - -
20,000 OBSERVATIONS.
FREQUENCY.
2800
2400
2000
1600
1200
800
400
9
11
13
15
17
BREAKING LOAD (OZS).

FIG. 1

with regard to the selection and stability of type—the use of Type IV equation—

$$y=6569{\cdot}974\left(1+\frac{x^2}{24{\cdot}45064}\right)^{-12\cdot77403} e^{-3\cdot024708\tan^{-1}x/4\cdot94476}$$

Applying the χ^2, P test, the value of χ^2 is found to be 82·615 and P equal to zero. This demonstrates that the description of the experimental series by Type IV equation is absolutely impossible. In Table II the theoretical frequency distribution is given.

EXAMINATION OF HETEROGENEITY IN THE GENERAL COMPLEX

From the foregoing discussion it could be stated that in no case an hypothetical series conformable to the normal distribution could be adduced, and further attempts to represent the observed distributions by one of the Pearsonian types of equation proved abortive. The explanation of the failure to establish a satisfactory working hypothesis lies in the fact that the experimental series are not homogeneous and that the heterogeneity may be due to variations in count.

This circumstance is beyond what is admissible by the pure theory. The observations being liable to the effects of this imperfection, an improved method of expressing the test results should be employed. The specific relationship between breaking-load and count was determined by the product-moment method. The slope of the regression lines exhibits a linear trend deviating from the straight line near the ends of the range. The association of variation between the variable
correlation given by the formula–

$$r=\overline{\quad}\,N.\sigma_x\sigma_y$$

was found to be negative in sign and to have the values 0·8584, 0·8802, 0·8672 and 0·7802 for Surat, Punjab-American, Dharwar 20's, and Dharwar 40's yarns respectively. The high values of the coefficients signify perfect dependence between the attributes of the material—a well-marked relation of the highest importance.

To modify the influence of count variations on strength measurements, recourse is had to the usual practice of expressing results of strength tests as joint product measurements of strength and count. It is assumed that the product quantity is constant for a particular count value of the yarn. A correction, therefore, in the crude values of strength measurements is made expressing them as joint product measurements of strength and count with regard to the four single-thread series.

DISCUSSION OF SINGLE-THREAD COUNT × STRENGTH RESULTS

The character of the original series is altered when its measurements are expressed as count-strength product quantities. Accordingly, for judging the theoretical constitution of these series, Table III is compiled giving the determinations of frequency-constants and their probable errors.

The frequency-constants of Surat 20's results indicate that the difference in the value of β_2 from the limit three is less than the probable error. The skewness factor being eight times the probable error renders the distribution a significantly skew curve. Judging from the values of moment coefficients the type of equation suitable for the frequency distribution is Type I.

$$y = 446{\cdot}04\left(1+\frac{x}{9{\cdot}652685}\right)^{18{\cdot}35806}\left(1-\frac{x}{4{\cdot}049685}\right)^{7{\cdot}69984}$$

Testing for "goodness of fit" the value of χ^2 is of the order 7·611 giving the value of $P=0{\cdot}370$. The chances are that in 37 cases out of a hundred we would on a random selection get more improbable results than the one that is obtained. The agreement is therefore satisfactory.

Table III

Statistical Constants and their Probable Errors

(Single-thread Count × Strength Test Series)

Statistical Constants	Surat 20's	Punjab-American 20's	Dharwar 20's	Dharwar 40's
Total number of observations ...	1,335	800	800	800
Mean value	226·833	198·012	264·450	238·775
Mode	228·835	194·960	268·482	238·638
Moment coefficient β_1	0·087	0·062	0·217	0·001
Probable error of β_1 from moments	0·022	0·019	0·048	0·000
Moment coefficient β_2	2·933	2·673	2·977	2·735
Probable error of β_2	0·095	0·078	0·138	0·067
Skewness	−0·170	0·176	−0·304	0·014
Critical function $\varkappa_1$	−0·395	−0·840	−0·698	−0·533
Probable error of $\varkappa_1$	0·164	0·120	0·186	0·139
Critical function $\varkappa_2$	−0·169	−0·056	−0·247	−0·001
Probable error of $\varkappa_2$	0·119	0·024	0·107	0·000
Standard deviation	11·759	17·300	13·263	9·638
Coefficient of variation	5·187	8·736	5·013	4·035

With regard to Punjab-American results, from Table III it will be seen that the difference in the value of β_2 from three is less than three times the probable error of β_2. The value of skewness being six times the probable error indicates that it is a skew curve. As in the previous case from the value of moment coefficients we infer that the distribution could be described by Type I equation—

$$y = 174{\cdot}947\left(1+\frac{x}{4{\cdot}531705}\right)^{3{\cdot}425904}\left(1-\frac{x}{8{\cdot}044785}\right)^{6{\cdot}081741}$$

The fit of the equation judged from the P,χ^2 test gives $\chi^2=21{\cdot}241$ which gives $P=0{\cdot}0118$. The fit is evidently not so close but by no means so poor a fit as to be discarded.

Judging from the values of frequency-constants of Dharwar 20's results, it will be noticeable that the difference in the value of β_2 from three is less than the probable error. However, there is marked skewness in the frequency distribution due to the fact that the skewness factor is about ten times the probable error. Here again the equation to the curve is Type I—

$$y = 236{\cdot}9668\left(1+\frac{x}{8{\cdot}99795}\right)^{9{\cdot}930644}\left(1-\frac{x}{2{\cdot}89839}\right)^{3{\cdot}198826}$$

Applying the P,χ^2 test the value of $\chi^2=17{\cdot}11$ which gives the value of $P=0{\cdot}009$. This agreement is very unsatisfactory but it must not be supposed

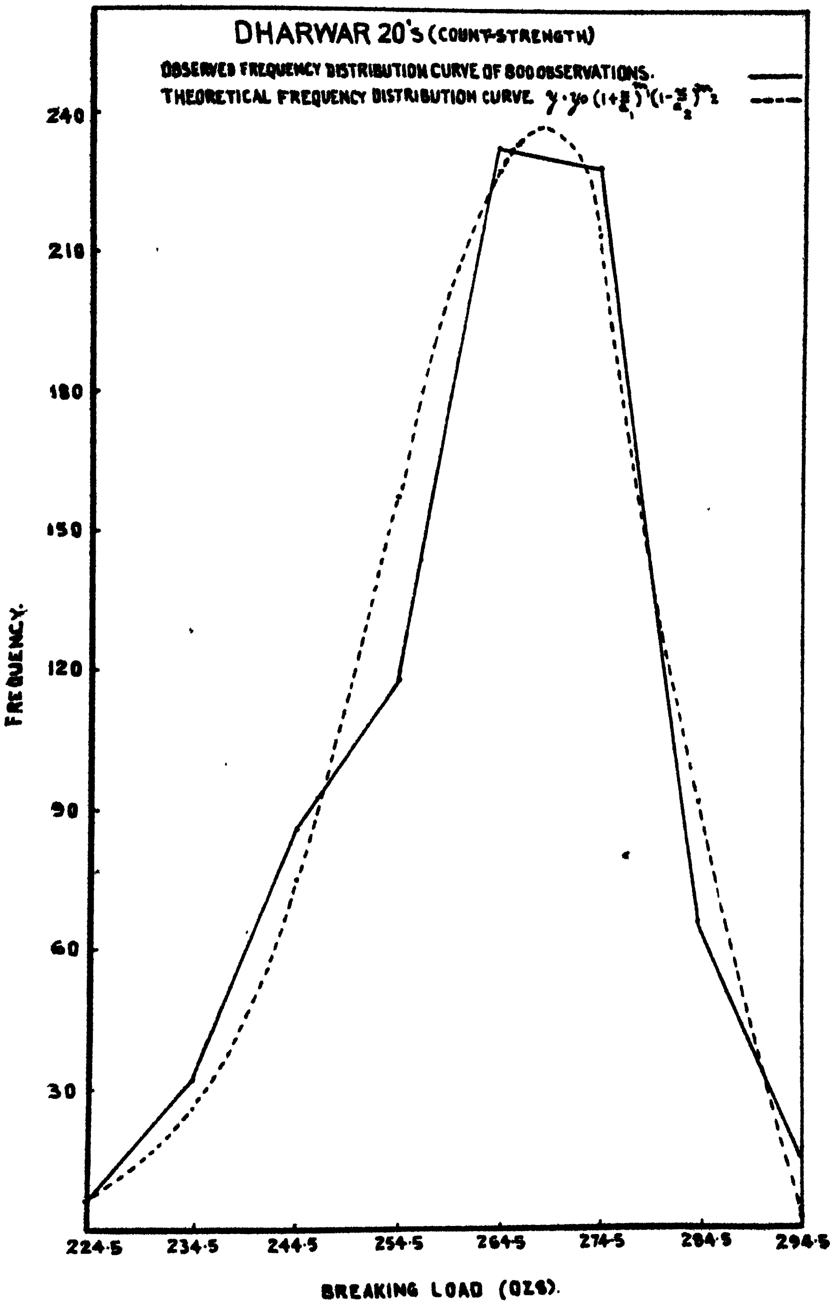
DHARWAR 20's (COUNT-STRENGTH)
OBSERVED FREQUENCY DISTRIBUTION CURVE OF 800 OBSERVATIONS.
THEORETICAL FREQUENCY DISTRIBUTION CURVE. $y = y_0 (1+\frac{x}{a_1})^{m_1} (1-\frac{x}{a_2})^{m_2}$
240
210
180
150
120
90
60
30
FREQUENCY.
224·5
234·5
244·5
254·5
264·5
274·5
284·5
294·5
BREAKING LOAD (OZS).

FIG. 2

that the curve does not fit the observations. The low value of P is due mainly to one point on the scale at which the difference between the observed and theoretical frequency is 9·272, nearly half the total value of the χ^2 index. This particular deviation is for the 254·5 class in which the difference of 38·0346 represents 3·39 times the standard error of sampling or five times the P.E. of sampling. A deviation of this amount would occur about once in each 1,000 trials and might be accounted for by mere chance fluctuations of sampling. The Type I curve, therefore, gives a reasonably good fit and may be employed for describing the given distribution.

Lastly, with regard to Dharwar 40's results, not only is the difference in the value of β_1 from zero less than its probable error, and of β_2 from three less than three times the probable error, but skewness is also less than the probable error. The equation to the curve is therefore given by the normal law—

$$y=319{\cdot}1538\ e^{-x^2/1{\cdot}857821}$$

The test of "goodness of fit" gives the value of $\chi^2=3{\cdot}6512$ which gives $P=0{\cdot}7228$. In 72 cases out of a hundred such trials the chances are that we should on a random selection get more improbable results than we have obtained. The fit is therefore remarkably good for the test data.

The theoretical distributions obtained for the four series by the above-mentioned equations are given in Table IV, and a typical case of Dharwar 20's is graphically represented in Fig. 2.

Table IV

Observed and Theoretical Frequency Distribution

(Single-thread Count × Strength Test Series)

SURAT 20's			PUNJAB-AMERICAN 20's			DHARWAR 20's			DHARWAR 40's		
Values	Observed Frequency	Theoretical Frequency	Values	Observed Frequency	Theoretical Frequency Type I	Values	Observed Frequency	Theoretical Frequency Type I	Values	Observed Frequency	Theoretical Frequency Normal
—	—	—	148·5	2	—	—	—	—	—	—	—
177·5	—	—	158·5	7	6·32	224·5	6	6·56	209·5	4	4·71
187·5	6	3·73	168·5	48	48·91	234·5	32	25·53	219·5	48	50·71
197·5	29	27·40	178·5	98	115·63	244·5	86	75·06	229·5	223	207·51
207·5	115	118·54	188·5	193	165·23	254·5	118	156·03	239·5	295	316·04
217·5	320	301·35	198·5	176	172·16	264·5	248	228·20	249·5	189	179·89
227·5	413	443·44	208·5	119	139·67	274·5	229	214·08	259·5	39	38·06
237·5	339	337·55	218·5	78	89·33	284·5	66	91·99	269·5	2	3·04
247·5	106	98·15	228·5	60	43·88	294·5	15	2·01	—	—	—
257·5	7	4·04	238·5	18	15·37	—	—	—	—	—	—
267·5	—	—	248·5	1	3·51	—	—	—	—	—	—
—	—	—	258·5	—	—	—	—	—	—	—	—

DISCUSSION OF LEA AND BALLISTIC STRENGTH RESULTS

Each of the observed series of lea and ballistic tests was subjected to the same statistical analysis as was employed for single-thread test results. With regard to the experimental series of lea strength test results of Berar 10's, it will be observed from Table V that the distribution can be described by a normal curve having the equation—

$$y=139{\cdot}5581\ e^{-x^2/10{\cdot}4597}$$

Testing for "goodness of fit", $\chi^2=10{\cdot}6$, which gives $P=0{\cdot}39$. The chances are that in 39 cases out of a hundred such trials we would get more improbable results than the one that is obtained. The fit can therefore be considered a good one. In Table VI the theoretical distribution corresponding to observed series is given.

The observed series for ballistic work of rupture test results in Table V demonstrates the applicability of the selected type equation, *viz.* Type V—

$$y=y_0x^{-48\cdot88615}\,e^{587\cdot172/x} \text{ where } \log y_0=76\cdot26777$$

Applying the (P,χ^2) test, it is found that $\chi^2=25\cdot08$ which gives $P=0\cdot000739$. A comparison of the frequencies shows that this is due to abnormal contribution of three groups far down the curve, the total contribution of which to the χ^2 index is 17·06. But for these discrepancies the remaining ratios in the χ^2 dispersion justify the hypothesis of Type V distribution. The theoretical distribution calculated from the equation is also given in Table VI.

Table V

Statistical Constants and their Probable Errors

(Lea and Ballistic Test Series)

Statistical Constants	LEA			BALLISTIC		
	Berar 10's	Dharwar 20's	Kampala 40's	Berar 10's	Dharwar 20's	Kampala 40's
Total number of observations ...	800	700	800	800	600	800
Mean value	643·55	1422·5	1728·05	1078·75	1157·87	1578·1
Mode	640·69	1436·12	1727·82	1099·24	1125·79	1529·22
Moment coefficient β_1	0·003	0·128	0·0	0·364	1·683	1·983
Probable error of β_1 from moments	0·001	0 071	0·0	0·099	—	—
Moment coefficient β_2	2·840	3·702	2·789	3·694	5·559	6·518
Probable error of β_2	0·093	0·433	0·086	0·365	—	—
Skewness	0·031	−0·137	0·002	−0·277	0·639	0·573
Critical function $\varkappa_1$	−0·330	1·018	−0·423	0·294	0·068	1·088
Probable error of $\varkappa_1$	0 186	0·731	0·171	0·501	—	—
Critical function $\varkappa_2$	−0·007	0·098	−0·0	1·015	1·058	2·052
Probable error of $\varkappa_2$	0·004	0·064	0·0	—	—	—
Standard deviation	91·475	99 112	100·937	73·949	49·440	85·289
Coefficient of variation	14·36	6·97	5·84	6·86	4 27	5·40

When the lea test results of Dharwar 20's are judged by the P.E. of the constants given in Table V, it will be noted that the frequency-constants do not differ significantly from normal theory. But as skewness is about 4·4 times the probable error we are probably just reaching a degree of skewness in the population for which the normal theory breaks down. Judged by the value of criterion $\varkappa_2=0$, $\beta_1=0$, and $\beta_2>3$, the theoretical distribution appropriate to the observed frequency distribution is a Type VII equation—

$$y=120\cdot5011\left(1+\frac{x^2}{64\cdot77969}\right)^{-6\cdot775626}$$

Proceeding to apply the P,χ^2 test, $\chi^2=13\cdot25$, which gives $P=0\cdot1033$, the value of P signifies that one in ten trials would give a fit as bad or worse to this type of curve, thus illustrating a fair agreement with experimental results. In Table VI the theoretical frequency distribution calculated from the equation is given and shown graphically in Fig. 3.

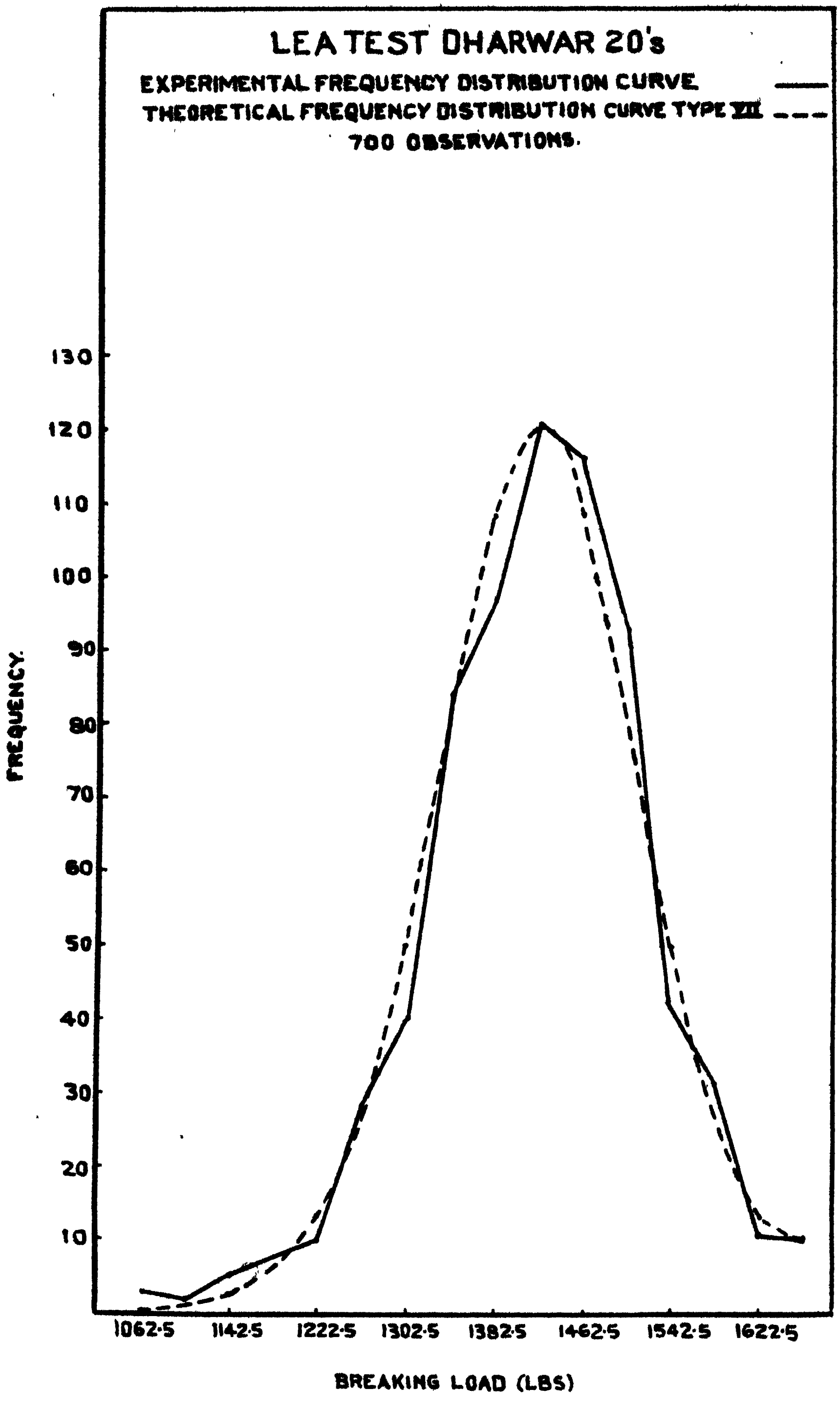
LEA TEST DHARWAR 20's
EXPERIMENTAL FREQUENCY DISTRIBUTION CURVE ——
THEORETICAL FREQUENCY DISTRIBUTION CURVE TYPE VII - - -
700 OBSERVATIONS.
FREQUENCY.
130
120
110
100
90
80
70
60
50
40
30
20
10
1062·5
1142·5
1222·5
1302·5
1382·5
1462·5
1542·5
1622·5
BREAKING LOAD (LBS)

Fig. 3

Table VI

Observed and Theoretical Frequency Distributions

(Lea and Ballistic Test Series)

LEA									BALLISTIC								
Berar 10's			Dharwar 20's			Kampala 40's			Berar 10's			Dharwar 20's			Kampala 40's		
Values	Observed Frequency	Theoretical Frequency Normal Curve	Values	Observed Frequency	Theoretical Frequency Type VII	Values	Observed Frequency	Theoretical Frequency Normal Curve	Values	Observed Frequency	Theoretical Frequency Type V	Values	Observed Frequency	Theoretical Frequency Type III	Values	Observed Frequency	Theoretical Frequency Type VI
364·5	—	1·85	1062·5	3	0·49	1407·5	1	1·16	837·5	5	3·27	1058·5	1	—	1420·5	9	—
404·5	7	4·80	1102·5	2	1·14	1447·5	1	2·77	877·5	15	8·09	1078·5	16	—	1460·5	54	52·99
444·5	12	13·46	1142·5	5	2·65	1487·5	8	7·61	917·5	19	18·86	1098·5	51	74·57	1500·5	120	164·19
484·5	31	31·27	1182·5	7	6·03	1527·5	19	17·90	957·5	35	40·57	1118·5	103	117·36	1540·5	200	184·60
524·5	55	60·16	1222·5	10	13·20	1567·5	38	36·05	997·5	71	78·08	1138·5	127	114·25	1580·5	166	147·47
564·5	120	95·87	1262·5	28	27·00	1607·5	70	62·15	1037·5	114	129·19	1158·5	104	92·73	1620·5	120	100·49
604·5	108	126·57	1302·5	40	49·90	1647·5	81	91·76	1077·5	190	173·70	1178·5	80	68·34	1660·5	50	62·96
644·5	138	138·44	1342·5	84	80·29	1687·5	122	116·03	1117·5	195	175·43	1198·5	38	47·43	1700·5	37	37·65
684·5	129	125·45	1382·5	97	108·62	1727·5	115	125·65	1157·5	114	118·84	1218·5	32	31·59	1740·5	12	21·96
724·5	90	94·17	1422·5	121	120·50	1767·5	120	116·52	1197·5	28	45·65	1238·5	15	20·43	1780·5	11	12·62
764·5	56	58·57	1462·5	116	108·62	1807·5	95	92·55	1237·5	10	7·70	1258·5	10	12·92	1820·5	9	7·22
804·5	35	30·17	1502·5	93	80·29	1847·5	58	62·95	1277·5	4	0·38	1278·5	9	8·02	1860·5	4	4·13
844·5	13	12·87	1542·5	42	49·90	1887·5	43	36·67	—	—	—	1298·5	4	4·91	1900·5	2	2·37
884·5	4	4·55	1582·5	31	27·00	1927·5	21	18·29	—	—	—	1318·5	3	2·97	1940·5	2	1·36
924·5	2	1·73	1622·5	11	13·20	1967·5	2	7·81	—	—	—	1338·5	4	1·78	1980·5	4	0·79
—	—	—	1662·5	10	10·32	2007·5	6	4·06	—	—	—	1358·5	1	1·05	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	1378·5	2	0·62	—	—	—

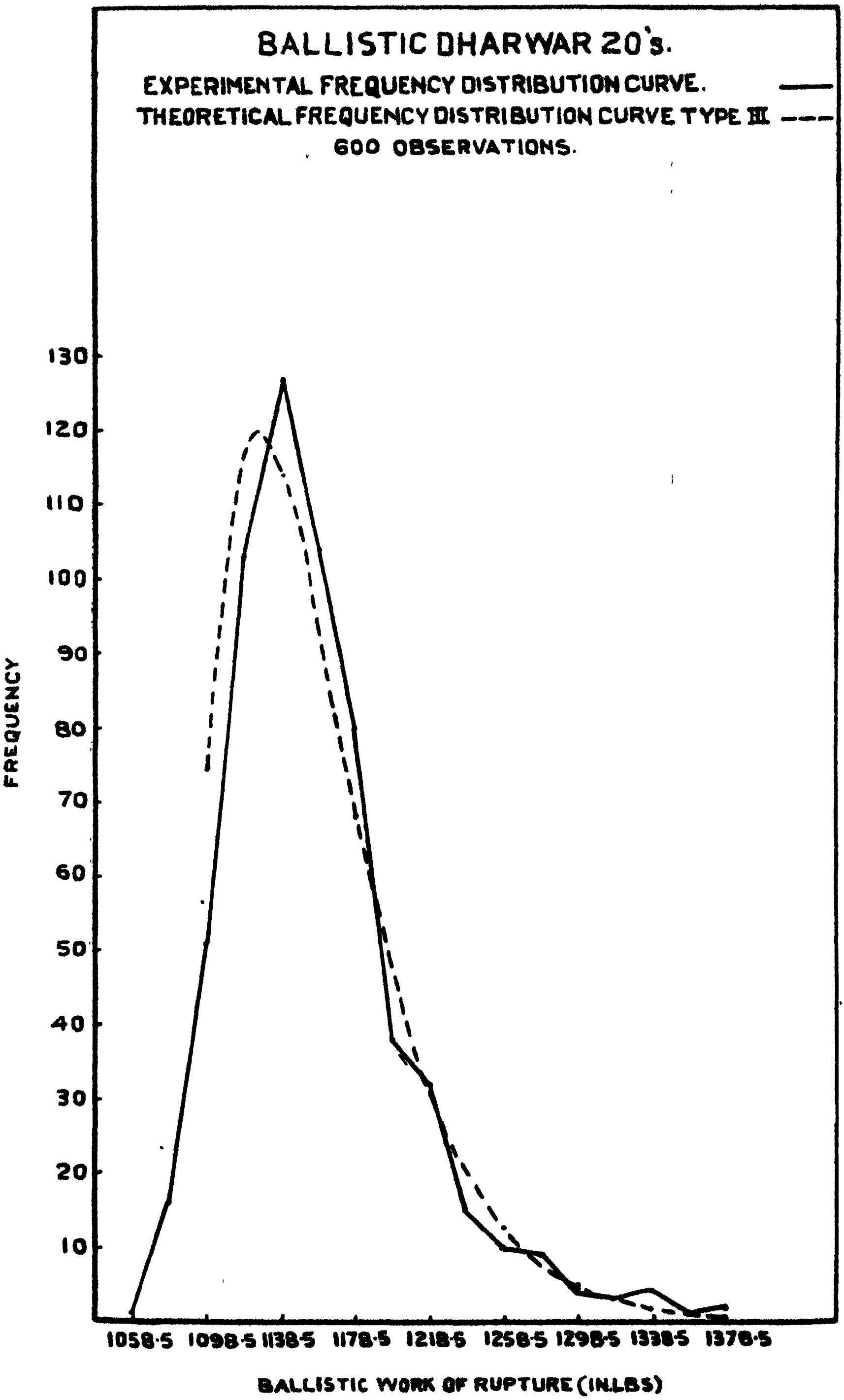
BALLISTIC DHARWAR 20's.
EXPERIMENTAL FREQUENCY DISTRIBUTION CURVE. ——
THEORETICAL FREQUENCY DISTRIBUTION CURVE TYPE III - - -
600 OBSERVATIONS.
FREQUENCY
130
120
110
100
90
80
70
60
50
40
30
20
10
1058·5
1098·5
1138·5
1178·5
1218·5
1258·5
1298·5
1338·5
1378·5
BALLISTIC WORK OF RUPTURE (IN.LBS)

Fig. 4

Turning to the consideration of the ballistic test results of the same yarn it will be clear from Table V that the frequency-constants differ significantly from normal theory.

Since $2\beta_2$ is equal to $6+3\beta_1$, the theoretical curve that would best describe the observed series is Type III having the equation—

$$y=119{\cdot}8773\left(1+\frac{x}{2{\cdot}206783}\right)^{1\cdot376091} e^{-0\cdot623573x}$$

The agreement of hypothesis to data by the P,χ^2 test is indicated by the value of $\chi^2=14{\cdot}9945$, which gives $P=0{\cdot}0911$. Hence, in nine trials out of 100, we should obtain as bad or worse a fit. The agreement with observation is therefore satisfactory. The theoretical distribution calculated from this equation and its agreement with observed series is shown in Table VI and Fig. 4.

It now remains to consider what hypothesis can best represent the lea and ballistic test results of Kampala 40's. With regard to lea test results, the ratios of the differences between the observed and theoretical values of the frequency constants to their probable errors given in Table V demonstrate that there is no significant departure from normal theory, and therefore the normal equation—

$$y=126{\cdot}4759\, e^{-x^2/12\cdot73545}$$

represents the experimental series.

When the agreement is tested for "goodness of fit", we have $\chi^2=7{\cdot}16$, which gives $P=0{\cdot}7099$. The fit is excellent. Table VI exhibits the agreement of theoretical distribution with experimental data.

Passing on to the consideration of ballistic test results of the same yarn, it will be noticed from the values of frequency-constants given in Table V that the normal curve cannot be used to represent the given distribution. The value of the moment coefficients β_1 and β_2 being $1{\cdot}983$ and $6{\cdot}518$, and the criterion $\varkappa_2>1$, the type of curve that would best describe the experimental distribution is Type IV having the equation—

$$y=150{\cdot}31024\left(1+\frac{x}{22{\cdot}5462}\right)^{-24\cdot37045}\left(1+\frac{x}{3{\cdot}731088}\right)^{2\cdot86749}$$

Applying the P,χ^2 test of fit the value of $\chi^2=30{\cdot}3084$, which gives $P=0{\cdot}0000038$. This is an extremely poor fit, but it is to be accounted for by reason of misfit at the start of the curve and the large value of χ^2 is entirely seen to arise from this discrepancy, otherwise the agreement for the main portion of the statistics is quite what one would desire it to be. The values of the theoretical curve against the corresponding experimental distribution are set out in Table VI.

CONCLUSIONS

From the study of several forms of frequency distributions given by the three methods of strength testing the following important inferences could be drawn—

(1) The experimental distributions are not adequately fitted by Pearson curves, hence the variation is heterogeneous.

(2) There is a high correlation between strength and count.

(3) When correction is made for count by using count-strength products the distributions are adequately represented by the Pearson type of curves and the heterogeneity is explained as due to a heterogeneity of count.

(4) The frequency-constants are given to show how far sampling theory based on assumptions of normality may be used for determining the significance of sub-samples or for inferring the minimum number of tests necessary for drawing reliable estimates.

REFERENCES

[1] K. Pearson, *Philosophical Magazine and Journal of Science*, 1900, **50**, 157-175.

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TRANSACTIONS

23—ABSORPTION OF WATER BY LINEN
PART II—FABRICS

By MARGARET H. PRESTON and J. A. MATTHEW

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SUMMARY AND CONCLUSIONS

Three methods of measuring absorbency are described and the reliability of each investigated. The wet surface method is shown to require very careful attention to various experimental conditions if the results are to be at all reliable. The sinking test does not appear to be a reliable method of comparing the absorbency of very different fabrics, and it gives no information as to the water holding capacity. The dipping method, as previously used for yarns can be equally well used for fabrics and appears the most reliable and easily carried out method; measurements of completeness of wetting, water held after dipping and after mangling can all be carried out on the one sample.

The results obtained from samples in the loomstate, finished, and laundered conditions are discussed in detail, and the conclusions may be briefly summarised as follows, giving greatest attention to the laundered fabrics, as this is the service condition for most fabrics where absorbency is one of the most important properties. In laundered linen, plain woven, and made from bleached yarn or bleached in the piece, it is found that—

(1) The effect of yarn twist on the completeness of wetting is negligible. The per cent. water held after dipping shows a steady decrease from a maximum at a certain yarn twist, but this difference is not shown after mangling.

(2) The per cent. water held after dipping and also after mangling is greater in cloth made from tow yarn than in similar cloth made from line yarn.

(3) The completeness of wetting after a given dipping treatment is not affected by the closeness of the weave. The per cent. water held after dipping depends on the completeness of wetting, but also in addition it decreases rapidly with increased ends per inch in the cloth. The water held is shown to be directly related to the compactness of the cloth, whilst the effect of changing the ends per inch may be approximately expressed by the relation $(P-50)\,n=\text{constant}$, where P=per cent. water held, n=number of ends per inch warp or weft with constant weft or warp respectively. The use of such a relation is discussed.

(4) The completeness of wetting depends to a very great extent on the cleanliness of the fibre surface, particularly as regards its freedom from materials of a fatty nature. During 15 seconds immersion in water at 30° C. all linen which has been laundered, even brown or partially bleached, wets fairly completely. The wetting is complete with fully bleached cloth. Also fully bleached cloth has rather greater water holding capacity and more water is expressed on mangling, so it will dry quicker than cloth not fully bleached.

(5) The completeness of wetting is not found to vary definitely with the fineness of the yarn, but some difference is found between cloths made from the same yarns, in which the finishing conditions have varied. Cloths from yarns of different sizes show differences in water holding capacity in consequence of the effect of the structure on the compactness of the cloth.

(6) The type of weave has very small effects on the completeness of wetting, but it may affect the water holding capacity through its effect on the compactness of cloth. Thus a twill weave will hold more water than a plain weave and a honeycomb slightly more than a huck or a diaper. These differences are very much less pronounced after mangling.

INTRODUCTION

In a previous paper[1] experimental measurements of the absorbency of flax yarns for water were recorded and discussed. In the present paper similar measurements are recorded on a variety of linen fabrics. Some of these materials were made from the same yarn as was employed in the yarn tests. The series of fabrics selected for test include variations in structure such as yarn twist, closeness of weave, type of weave, weight of cloth. In addition to the previous method of measurement, in which wetting was effected by immersion of the sample in water, other methods have been investigated for use in the case of fabrics, and these are discussed.

Since absorbency of linen is of supreme importance in towels and similar articles, most of the work has been carried out on fabrics made from bleached yarns or piece bleached. In order to illustrate the effects which may result from changes in the condition of a given fabric, such as by change in finish, tests were made on cloth in the loomstate, after finishing and also after being laundered several times at a public laundry. The practical utility of articles of this kind is judged not only on the amount of water it can absorb, but on the rate at which the article can be dried after washing or after use. It is obvious that for given drying conditions with a given cloth, the time of drying will depend on the initial amount of water held. Cloths which hold the most water when fully saturated would therefore naturally be at a disadvantage as regards time of drying from this state compared with a less absorbent article. However, in practice, cloths would not be dried from a fully saturated condition; for example, after washing, a good deal of the water held would be eliminated by pressure in a mangle or by other means. To obtain data on this aspect of absorbency, measurements were made in a good many cases of the water held after being fully saturated and passed through a mangle in which the pressure between the rollers was maintained constant.

EXPERIMENTAL METHODS

1—Dipping Method

In this method the apparatus used for yarn as previously described[1] was used in exactly the same way except that the yarn was replaced by a long narrow strip of cloth, for example 1 yard long by ½ in. width, weighing 1½–2 grammes. This strip was usually cut from the centre of the cloth in the warp direction. The dipping is effected by running the cloth at a fixed rate below the water surface. Determinations of the total water absorbed and the completeness of wetting on emerging were made as described for yarns. Some preliminary tests were made varying the time of immersion at a fixed water temperature, and with fixed time of immersion varying the temperature of water. The object of these tests was to establish standard experimental conditions which would be suitable for testing fabrics showing wide variations of absorbency. It was considered that these conditions should be established to suit fabrics of low absorbency, and so the measurements were made on two loomstate samples made from boiled and bleached yarns respectively.

The results were similar to those obtained from yarns. At a given water temperature the apparent density increases with increasing time of immersion, but attains a constant value less than that corresponding to complete wetting, depending on the temperature. The graph for per cent. water held against time of immersion follows a similar course, as, of course, the water held is proportional to the completeness of wetting. For these particular samples at 15° C. the completeness of wetting was not increased by prolonging the immersion beyond 6 seconds. With a constant time of immersion in water, the apparent density or completeness of wetting increased progressively with rise of temperature. The water held increased with temperature, owing to the more complete wetting, but a maximum was reached at about 50° C. and followed by a decrease in spite of a still further increase in completeness of wetting. Very similar behaviour was found in the case of grey wet spun yarns.

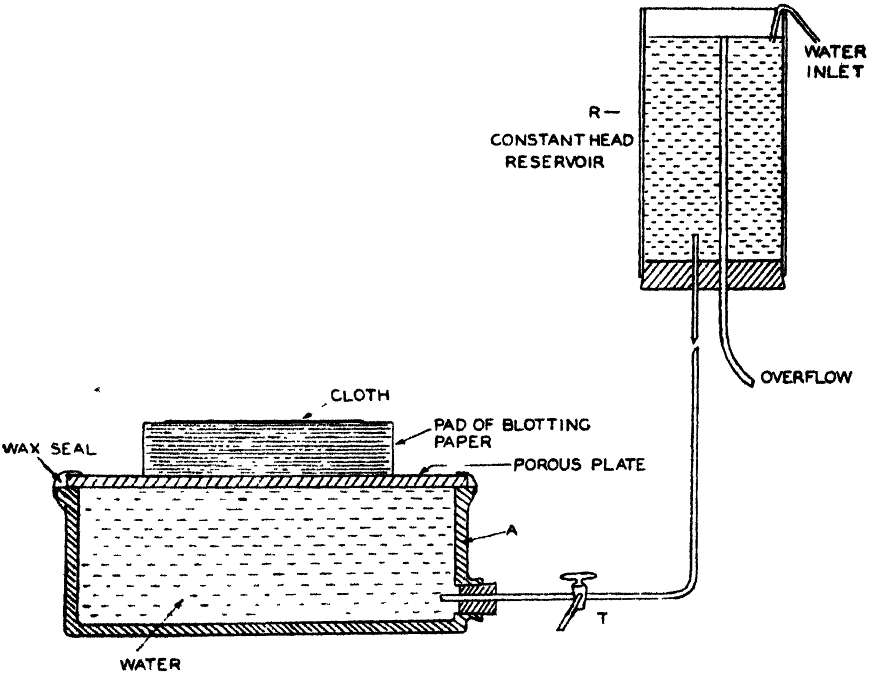


FIG. 1

As regards the experimental conditions most suitable for comparative tests, the same conclusions hold as for yarn. Most of the comparisons of different cloths have been determined at 15° C., 15 seconds immersion. Under these conditions differences between various cloths will be most pronounced and therefore most easily determined. Also, except for a few particular cases, the absorbent properties in cold water or water up to body temperature are those of interest to the user.

2—Absorption from a Wet Surface

Whilst the previous method of wetting by "dipping" appeared to be quite satisfactory as a test method for comparing the absorbencies of different fabrics, there may be some doubt as to whether similar results would be obtained under practical conditions such as the absorption from a wet surface. Results are quoted by previous workers, e.g. Faber and Hadden[2] for absorbency of fabrics as the water absorbed from a wet surface such as wet blotting paper. The methods employed are indicated without recording detailed experimental conditions or precautions which must be observed to ensure reliable comparisons. It was considered advisable to investigate this method, not only to assess the value to be attributed to recorded observations, but also to compare results obtained by this method with those obtained by the dipping method.

Apparatus was set up designed with the object of enabling a porous surface such as blotting paper to be kept in a constantly wet condition. The arrangement is shown diagrammatically in Fig. 1. The glass cylinder A is covered by a porous porcelain plate 5 in. in diameter, the joint being made watertight by paraffin wax. The cylinder communicates by a side outlet through a three-way stopcock T to a constant head water reservoir R. By this means the glass cylinder can be completely filled with water and a small constant pressure of about 15 in. of water maintained, so that a constant leakage may occur through the porous plate. It was found difficult to maintain conditions such that the plate surface should be evenly wetted but not actually flooded. To overcome this a good leakage through the porous plate was allowed and a pad of blotting paper was added until a surface of the required degree of wetness was obtained. The method of experiment then adopted was to cut a sample of the fabric 3 in. square and weigh. This was then placed flat on the wet test surface for a certain time when it was placed in a glass weighing bottle and the increase in weight obtained. The sample was then replaced on the wet surface for a further period and so on. In this way the water picked up was determined for varying times of contact. The early trials gave very variable results. These were gradually eliminated and conditions found by which reliable results could be obtained, but the experience emphasises that unless special precautions are taken, very misleading results may be obtained.

The following points were found to be important—

(1) It is better to lay the sample on the wet surface and flatten out, for example with the side of a glass rod. Attempts were made to impose a constant pressure with the wet surface by placing a glass plate over the sample, but this was found to cause irregularities.

(2) The height of the water in the reservoir must be constant. The saturation value for the water held was found to increase with the head applied.

(3) The paper pad should be allowed to absorb from the porous plate for at least two hours before placing on a fresh dry sample of fabric. This is not necessary if a partially saturated sample is being replaced.

(4) When repeated weighings are made on the same sample, some water drains off and is left in the weighing bottle. This should be dried each time before insertion of the sample, and the water left after removal should be regarded as excess water and its weight allowed for by subtraction.

When these precautions are observed results were obtained which could be repeated at different times with a fair agreement. The curves obtained were fairly smooth and of the type shown in Fig. 2, where the water held increases with time to a constant value. This constant or saturation value depends on the wetness of the surface. As a check on this method, an alternative procedure was used in which a sample was weighed after contact for a certain time, a fresh sample weighed after a longer contact and so on. This procedure uses a great deal more cloth and takes a much longer time to construct an absorption-time curve, but the procedure eliminates certain experimental corrections. Similar results were obtained by both methods and the actual values were in good agreement.

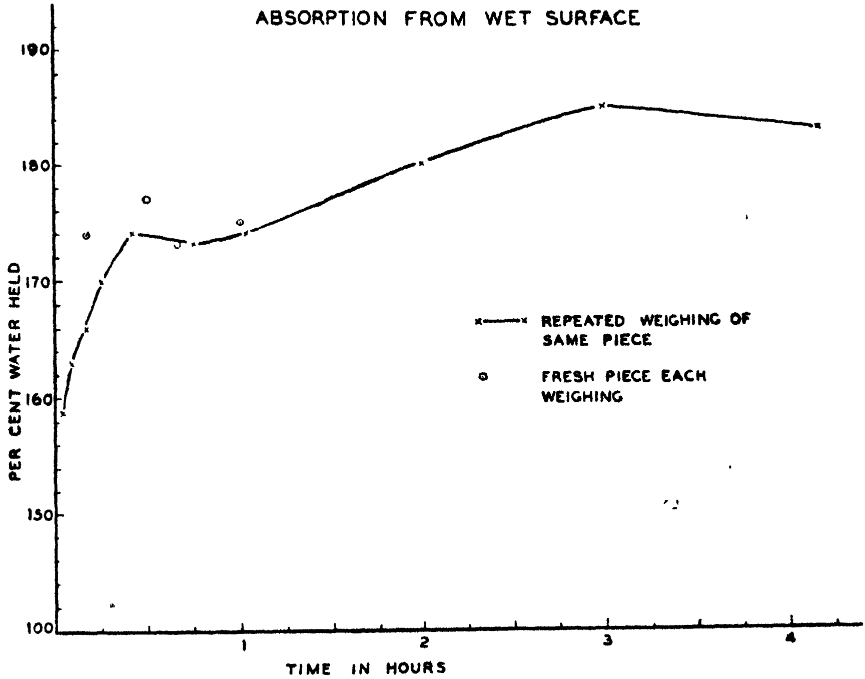


Fig. 2

It is evident that this method is unsuitable for the determination of the rate of absorption. To obtain accurate results a mean absorption-time curve as in Fig. 2 would have to be constructed from a number of samples, which would be a very lengthy process and involve much work. It can be seen from the curve which is for a bleached and laundered fabric that the rate of absorption is extremely rapid at first when the dry cloth is placed in contact with the wet surface, and that the rate of absorption gradually decreases as saturation is approached. The method could, however, be employed fairly satisfactorily and easily to determine the saturation value, in which case a sample would be left in contact for a fixed time and then the increase in weight taken; the time of contact must be such as to ensure complete saturation and this will vary with different materials.

The saturation value of the per cent. water held as determined by the wet surface method was compared with that obtained for the same cloth by the dipping method. The values by the two methods for a series of bleached and laundered linen cloths in which the yarn setting varies are summarised in Table I.

Both methods agree in showing that at saturation the per cent. water held decreases as the weave is made closer, so that either method would appear to give satisfactory comparative values. Throughout the series, the value given by the dipping method is consistently higher than that obtained from the wet surface method. Such a difference might be expected since in the dipping method both sides are directly in contact with the water and so can draw out from the bath a free film of water, whereas in the other method only one side is in direct contact.

A further test was made on a sample of cloth in an attempt to separate the total water held into that held as a free film of water on the surface, and that just required to saturate the cloth and fill the interspaces between the fibres in the yarn and between the yarns in the cloth. As an approximation the latter was assumed to be equal to the water held by a cloth fully wetted by immersion in water and then lightly mangled. A test was made by both methods in which such a lightly mangled specimen was used instead of a dry sample, when it may be assumed that the additional water picked up will all be held as a free film on the surface. The results were as follows—

	Per cent. Water Held	
	Dipping Method	Wet Surface Method
In wet mangled cloth	64·2	71·5
Total after rewetting	203·0	172·5
Surface water after rewetting ...	138·8	101·0

The relative values for total water held by the two methods are in good agreement with those in Table I, and the test shows that the difference between these values is due to difference in the amount held as a free surface film.

The dipping method is considered to be preferable as it is much more rapid in use, experimental precautions are not so necessary, and tests can readily be carried out in different liquids if desired and at various temperatures. For these reasons all the work on the comparison of different cloths was carried out employing the dipping method.

3—Sinking Method

A method known as the "Sinking Test" is frequently used[8] to test the relative merits of different wetting out agents which are used to increase the rate with which water and other liquids can wet out textile materials. There are several variations on the method, but in principle they all depend on the measurement of the time taken for a piece of fabric or other textile material placed in the liquid to sink. The fabric with its included air is less dense than water, but when it is wetted, the air is displaced and the cloth becomes denser than water and sinks. The method is sometimes used to test the absorbency of a textile. It has the advantage of extreme simplicity and rapidity. All that is required is to cut a sample of a certain size and shape, attach a small weight to the bottom to keep the sample vertical when in the water. The top of the specimen is gripped in a pair of forceps and quickly dipped below the surface of water in a glass beaker and released, at the same time starting a stop watch which is stopped when the specimen sinks and touches the bottom.

Table I

Per cent. water held (saturation)

Cloth. Plain weave. 2½ lb. D.S. line warp and weft

Cloth	Ends per inch		Per cent. Water Held	
Ref. No.	Warp	Weft	Wet Surface Method Room temperature ¼ hour contact	Dipping Method 15° C. 15 secs. immersion
45 CL	23·3	33·3	218	309
46 CL	28·7	33·3	192	270
47 CL	34·5	33·3	165	209
48 CL	43·2	33·3	141	172
49 CL	47·3	33·3	132	161
50 CL	51·4	33·3	116	149

Table II

Wetting in Sinking Test

Cloth Ref. No. 91 C. Plain weave from 40, 45's Boiled yarn, ends per inch 52·0 58·5. Water temperature 15° C.

Cloth	Time to Sink seconds	Condition after Sinking		Dipping Method 15 secs. immersion at 30° C.	
		Apparent Density	Per cent. Wetted	Apparent Density	Per cent. Wetted
Loomstate ...	35	1·02	54·3	1·35	85·7
Finished ...	28	1·24	73·2	1·42	91·7
Laundered ...	1	1·42	92·3	1·48	98·1

Some investigation of this method was made with the object of determining the significance of the result. The usual assumption is that the time to sink is an indication of the rapidity with which wetting occurs. This is only true if all materials reached a definite degree of wetting when sinking takes place. The test was carried out on pieces of a certain cloth in its loomstate, finished, and laundered conditions, which were known to vary considerably in absorbency, from tests made by the dipping method. As soon as the pieces had sunk they were extracted from the beaker and the apparent density determined as previously described, which enabled the estimation of the completeness of wetting of the sample when it sank. The results are shown in Table II, including for comparison the result obtained by the dipping method (but at 30° C.) for the completeness of wetting after 15 seconds immersion. It will be seen that the dipping method and the time to sink place the three samples in the same relative positions. In the dipping method the comparison is perfectly definite as the time factor is constant. In the sinking test, however, the results show that the test records the time for the samples to become wetted to varying degrees, whereas for a precise comparison on this basis the time should be obtained for all the samples to attain a constant degree of wetting. The sinking method is therefore not really a sound method of comparing absorbencies. This criticism does not apply when it is used to compare the efficiencies of wetting out agents, as then a standard cloth is used throughout a series of measurements, and it may be assumed that this will always sink when wetted to the same extent, and so the time to sink is a definite means of comparing the wetting power.

DISCUSSION OF RESULTS

Measurements were made by the dipping method of the absorbency of various types of linen cloths, having regard to the ease of wetting as shown by the apparent density after a fixed time of immersion and to the total water held (*a*) on leaving the water and (*b*) after a fixed mangling treatment. The tests were made on series of samples in which one structural factor was

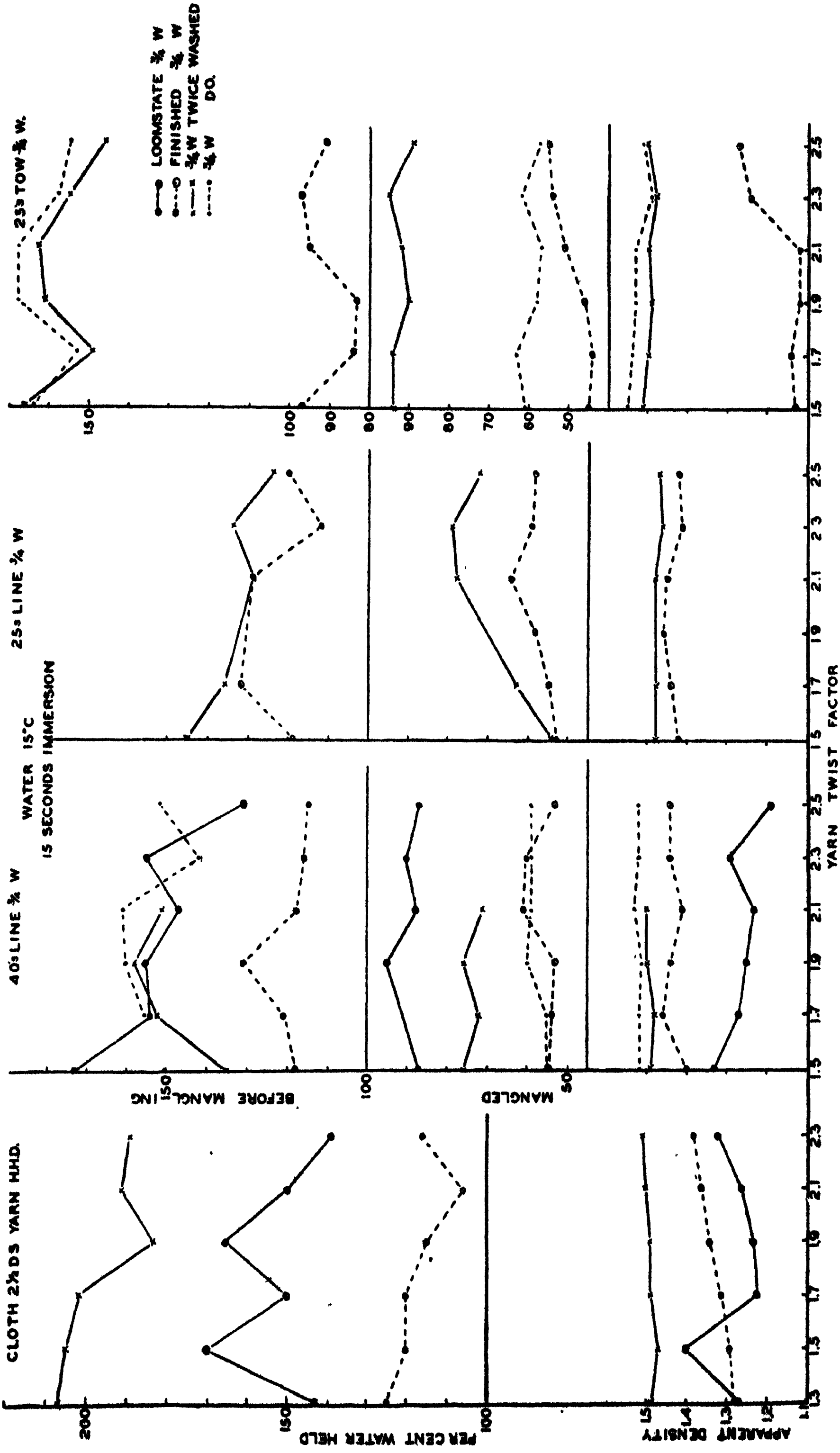

CLOTH 2½DS YARN H.H.D.
40's LINE % W
WATER 15°C
15 SECONDS IMMERSION
25's LINE % W
25's TOW % W.
LOOMSTATE % W
FINISHED % W
% W TWICE WASHED
% W DO.
PER CENT WATER HELD
BEFORE MANGLING
MANGLED
APPARENT DENSITY
YARN TWIST FACTOR
200
150
100
50
90
80
70
60
1.5
1.4
1.3
1.2
1.1
1.5
1.7
1.9
2.1
2.3
2.5

FIG. 3

varied, and on cloths in various conditions of finish. These results are tabulated and shown graphically and will be discussed in relation to the cloth structure and condition.

Effect of Yarn Twist

The results obtained from four sets of samples comprising cloths plain woven with a constant number of warp and weft ends per inch, from the same yarn spun with varying turns per inch, are set out graphically in Fig. 3. The particulars of the cloths are as follows—

(1) Warp and weft of 2½ lb. D.S. line yarn bleached H.H.D., 36·6 ends per inch, 33·3 picks per inch. Cloth beetled and calender finished without further bleaching.

(2) Warp and weft 40's line yarn, bleached ¾ white, 56·75 ends per inch, 54·25 picks per inch. Cloth finished by beetling and calendering, in ¾ white and also after cloth bleaching to full white.

(3) Warp and weft 25's line yarn, bleached ¾ white, 45 ends per inch, 41·5 picks per inch. Cloth finished as (2) in ¾ white state.

(4) Warp and weft 25's tow yarn, bleached ¾ white, 44 ends per inch, 44 picks per inch. Cloth finished as (2).

With each set, tests were made on the cloth in the loomstate, finished, and twice laundered conditions. The graph shows the apparent density after wetting which is proportional to the completeness of wetting, the per cent. water held on emerging from water at 15° C. after 15 seconds immersion, and after mangling. A uniform system is used throughout of indicating the values of the experimental results and of connecting them by lines.

The completeness of wetting is somewhat erratic with the loomstate samples, no doubt due to irregularity in the amount of tallow used on the warp for weaving; no consistent change with yarn twist is shown. In the finished cloth the results are much more regular, more completely wetted than the loomstate and on the whole show an increase in the completeness of wetting with increase of yarn twist. With the laundered cloths, the completeness of wetting is greater than with the finished cloth, and the effect of yarn twist is no longer definitely shown.

The per cent. water held is very erratic with the loomstate cloth, showing no decided variation with yarn twist, but definitely larger than with the finished cloth. The water held by the finished cloth shows some irregularity, but there is an indication that it decreases with increasing yarn twist. With twice laundered cloth the water held decreases with increasing yarn twist in the cloths from 2½ lb. and 25's line yarn. In the other two cases the water held attains a maximum value, the behaviour being consistent in the cloths finished from the loomstate and also after full bleaching. The fully bleached cloth holds more water than the cloth finished ¾ white, which is due to it being more completely wetted.

The results for the water held after mangling show less irregularity, but in none of the different cloth states is any consistent variation with yarn twist indicated.

From the point of view of the behaviour in service, the results from the twice laundered cloths are those of most interest, the others indicating the pronounced effect on absorbency of the presence of small quantities of fatty materials. Cloths made from ¾ white yarn or cloth which has been fully bleached and laundered, become almost completely wetted out after a short immersion in cold water, the effect of yarn twist being negligible. The amount of water held after dipping varies with yarn twist, showing a steady decrease from a maximum at a certain yarn twist; this effect of yarn twist is not shown after mangling. The per cent. water held after dipping and also after mangling is greater in cloth from tow yarn than in similar cloth from line yarn.

Effect of Closeness of Weave

Measurements were made on three series of cloths made from 2½ lb. D.S. line yarn, bleached H.H.D. with three yarn twists, each with increasing warp or weft ends per inch, for cloth in the loomstate, finished, and twice laundered states. The results with the cloths from yarn of 2·1 twist factor are shown graphically in Fig. 4; the results for the other yarn twists were of a similar nature.

The completeness of wetting after 15 seconds immersion in water at 15° C. shows some slight variation, but after twice laundering the degree of wetting is very high and constant for all the weaves.

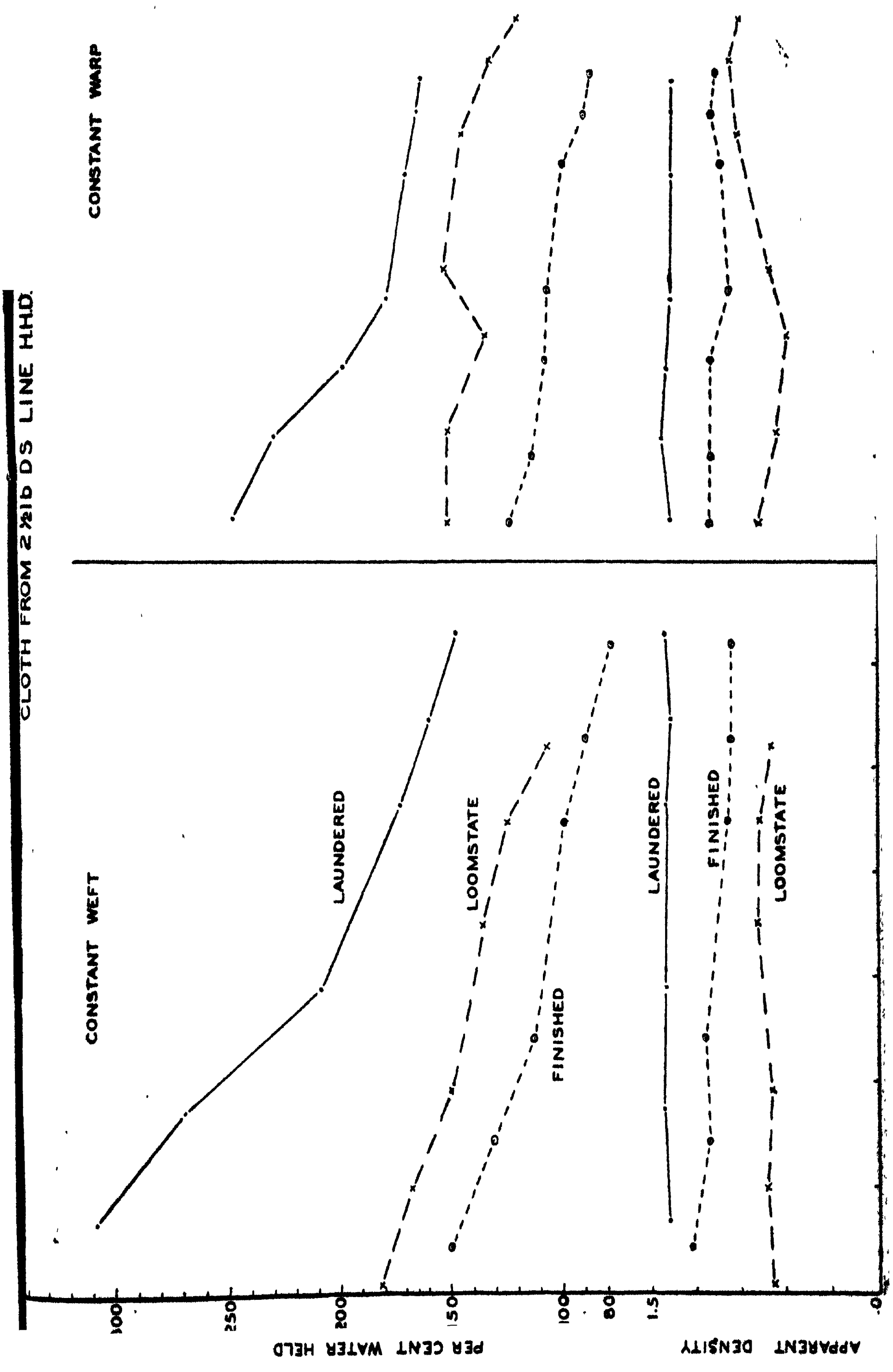
The per cent. water held is greatest for the laundered cloth and least for the cloth in its finished state. In all cases, the water held decreases with increasing closeness of weave, the effect being most pronounced with the laundered cloth.

Table III

Structure of Cloths with varying Ends per inch

Ref. No.	Loomstate Ends per inch Warp	Loomstate Ends per inch Weft	Twice Laundered Ends per inch Warp	Twice Laundered Ends per inch Weft	Finished wt./sq. yard, ounces	Compactness Apparent Density of Dry Cloth Loomstate	Finished	Twice Laundered
45 C	20·3	33·9	23·3	33·3	4·79	0·37	0·61	0·37
46 C	24·9	33·9	28·7	33·3	5·27	0·39	0·66	0·37
47 C	29·6	33·9	34·5	33·3	5·65	0·43	0·70	0·41
48 C	37·6	33·9	43·2	33·3	6·54	0·46	0·78	0·49
49 C	42·2	33·9	47·3	33·3	6·73	0·45	0·74	0·55
50 C	46·0	33·9	51·4	33·3	7·12	0·47	0·77	0·53
51 C	33·1	21·8	36·9	22·0	4·91	0·36	0·60	0·37
52 C	33·1	26·2	36·9	25·8	5·38	0·38	0·64	0·39
53 C	33·1	30·75	36·9	29·2	5·80	0·41	0·69	0·44
54 C	33·1	33·9	36·9	32·5	6·28	0·43	0·75	0·47
55 C	33·1	40·4	36·9	38·4	6·09	0·50	0·75	0·49
56 C	33·1	43·9	36·9	41·5	6·96	0·52	0·78	0·51
57 C	33·1	46·0	36·9	43·0	6·97	0·55	0·77	0·51

The rate of wetting is evidently a property of the yarn, depending on its freedom from impurities of a fatty or oily nature, The amount of water held evidently depends on the completeness of wetting of the yarn, but it also depends on the structure of the cloth. In Fig. 4 the values are plotted against the ends per inch as the superficial variable. Different cloths cannot be compared on this basis, but they can be compared in terms of the compactness of the cloth (measured as apparent density of the dry cloth) which expresses the magnitude of the air spaces between the yarns in the cloth; the higher the apparent density the smaller the air spaces. The structures of the cloths corresponding to Fig. 4 are shown in Table III. In each state, the compactness increases with increasing ends per inch warp or weft. The value of the apparent density is by far the highest for the finished cloth, whilst it is approximately the same for the loomstate and twice laundered cloths. It will be seen that a general relation appears to exist between the apparent


CLOTH FROM 2 ½lb DS LINE H.H.D.
CONSTANT WEFT
CONSTANT WARP
LAUNDERED
LOOMSTATE
FINISHED
LAUNDERED
FINISHED
LOOMSTATE
300
250
200
150
100
80
1.5
1.0
PER CENT WATER HELD
APPARENT DENSITY

density (compactness) and the water held. In each state, the completeness of wetting is fairly constant, and the decreasing water held is accounted for by the corresponding increase in compactness. The finished cloth is more completely wetted than the loomstate, but owing to the much higher compactness, the finished cloth holds less water. Since the loomstate and laundered cloths have approximately equal compactness, the difference in the water held is evidently due to the much greater completeness of wetting of the latter.

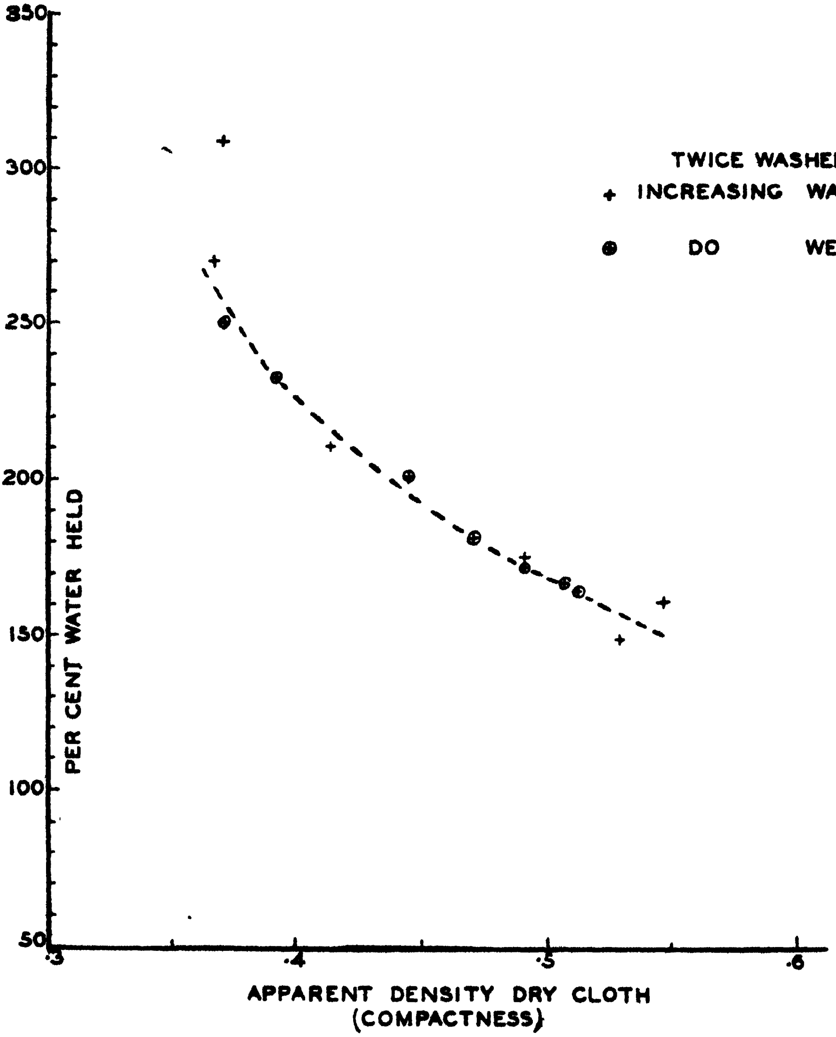


Fig. 5

The curves for water held by the laundered cloths with increasing warp and weft ends (the wetting of each being fairly complete and constant) appear to be somewhat different, but if these values are plotted against compactness as shown in Fig. 5, a smooth curve can be drawn through the whole of the points to represent each set equally well. Such a curve could be expressed by an algebraical equation, but this would not be of much interest since in practice cloths are not compared in terms of compactness.

The case of the laundered cloth is of most interest, and it is found that in this case the results can be expressed with sufficient accuracy for practical purposes by the simple relation $(P-50)\,n=K$

where P = per cent. water held

n = ends per inch warp or weft with constant weft or warp respectively

K = a constant.

The value of K will vary with the type of cloth. The value 50 is approximately equal to the per cent. water held by the mangled cloth.

A relation of this kind is very simply employed, for example, to calculate the change in the water holding capacity of a cloth on changing the setting of the warp or weft yarns. This should be useful, for example, in consideration of the design of towels and is probably all that is required from the practical standpoint. The actual design employed must compromise between the best structures to attain certain properties besides water absorption such as strength, feel, appearance, and resistance to wear. For instance in another paper[4] it is shown that the resistance to laundry wear increases very rapidly with increasing closeness of weave, and so it is obviously impossible to provide a towel which will have both maximum water holding capacity and maximum of resistance to wear.

Table IV

Variation of Structure with Treatment

Ref. No.	Figure Graph No.	Plain weave	Woven from Yarns	Wt./sq. yard, ounces	Ends per inch		Compactness (apparent density)
					Warp	Weft	
91 C	1	Loomstate	40 45's boiled	4·67	52·0	58·5	—
		Finished brown ...	—	4·66	55·75	56·0	0·53
		Full bleached ...	—	4·05	56·25	55·75	0·54
		Brown finish, twice washed	—	4·79	57·5	58·25	0·45
		Full bleach, twice washed	—	4·08	57·0	56·25	0·38
93 C	2	Loomstate	40 45's ¾ W.	5·11	51·5	60·5	—
		Finish ¾ W. ...	—	5·16	56·25	56·75	0·58
		Full bleached ...	—	4·14	58·0	56·75	0·56
		Finish ¾ W., twice washed	—	5·30	59·5	58·0	0·41
		Finish 4/4 W., twice washed	—	4·04	57·25	57·25	0·39
74 C	3	Loomstate	40 40's ¾ W.	4·78	53·25	53·5	0·41
		Finished ¾ W. ...	—	4·79	57·0	52·5	0·54
		Finished 4/4 W. ...	—	4·18	57·25	52·25	—
		Finish ¾ W., twice washed	—	—	—	—	—
		Finish 4/4 W., twice washed	—	4·11	57·1	53·25	0·41
59 C	4	Loomstate	2½ lb. D.S. line H.H.D.	5·8	33·75	35·0	0·50
		Finished H.H.D. ...	—	6·16	36·7	33·3	0·70
		Finished, twice ... washed	—	6·61	39·1	33·5	0·47

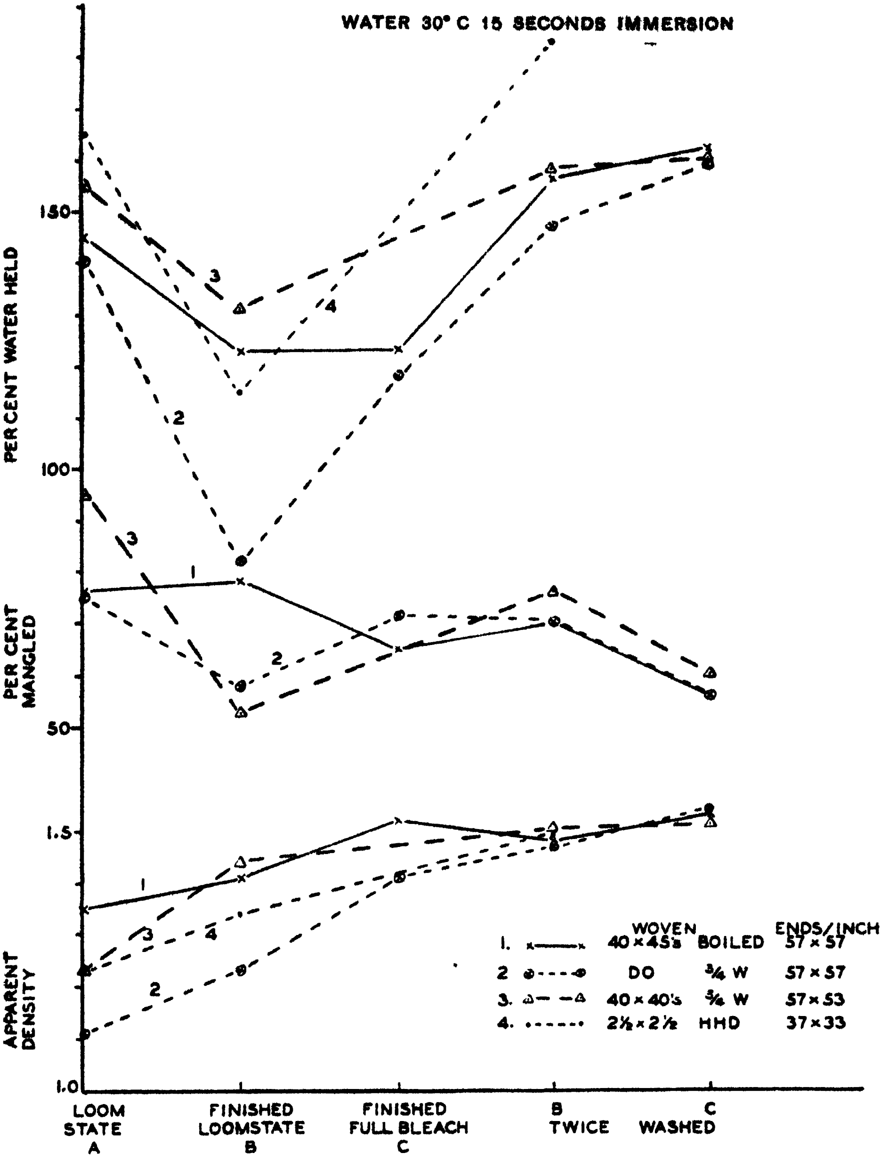


FIG. 6

Effect of Bleaching and Finishing Treatment

In the previous discussions considerable differences in behaviour of loom-state, finished, and laundered samples were pointed out. In order to permit of easy and direct comparison the results from four kinds of cloth, each of normal construction, are shown graphically in Fig. 6. In the course of the treatments changes in the structure take place by shrinkage, compression and so on, apart from chemical changes in bleaching, and the effect of these on the behaviour may have to be considered. The changes in structure corresponding to the specimens dealt with in Fig. 6 are shown in Table IV.

It will be seen that on wetting and finishing the loomstate cloth, a shrinkage in width and an outcome in length (shown by an increase in warp and a decrease in picks per inch) results, with a considerable increase in density owing to the reduction in thickness due to pressure effects. The structure is very similar whether the cloth is fully bleached or not further bleached before being given the same finish treatment. On laundering there is a shrinkage in width and length, together with a reduction in density.

Graphs 1 and 2 in Fig. 6 compare the behaviours of very similar cloths, woven from boiled and ¾ white yarns respectively. It will be seen that in the loomstate and loomstate finished conditions, the cloth from boiled yarn is more completely wetted and holds more water than that made from bleached yarn, and the difference is still maintained when both are fully bleached and finished. The difference appears to be a real one, unconnected with slight differences in structure, and it may be that the cloth from boiled yarn is smoother and freer from hairiness than that from bleached yarn.

The results are consistent in showing that the loomstate finished cloth wets more completely than the loomstate cloth, but holds less water, after mangling as well as after dipping. The increased wetting would be due to removal of impurities such as tallow used for warp dressing, and the smaller water holding capacity to the increased compactness after finishing. The fully bleached cloth wets more completely than the loomstate finished cloth, and as they are of approximately equal compactness, there is in consequence an increase in the water held. After finishing and twice laundering, the differences in the finished state become less marked, and in all cases the wetting is considerable and rather greater than with the finished cloth, and the per cent. water held is also higher. With the fully bleached and laundered cloths the wetting is practically complete and they hold slightly more water than the others. Evidently the completion of bleaching increases the ease of wetting of the material, but some resisting material is still left in or may be deliberately added during finishing, and this is removed on laundering. From Table IV it will be seen that the laundered fully bleached cloths are slightly less compact than the laundered loomstate finished cloths which would account for the greater per cent. water held after dipping; after mangling, however, these laundered fully bleached cloths hold less water than the laundered loomstate finished cloths. After twice laundering the behaviours of cloths woven from boiled and bleached yarns are closely equal, and after fully bleaching each before finishing and laundering, the behaviours are practically identical. From this it would appear that the last stage in bleaching has a greater effect on the absorbency than the early stages.

All linen which has been laundered, even brown or partially bleached, wets fairly completely during 15 seconds immersion in water at 30° C. (which is close to normal skin temperature) but the wetting is complete with fully bleached cloth, the water holding capacity is slightly greater and more water is expressed by mangling. A fully bleached linen therefore has distinct advantages for purposes such as towels.

Effect of Size of Yarn

In order to obtain data to connect absorbency with fineness of yarn, three sets of samples were tested, the structural particulars of which are summarised in Table V. These samples were not specially prepared, but were drawn

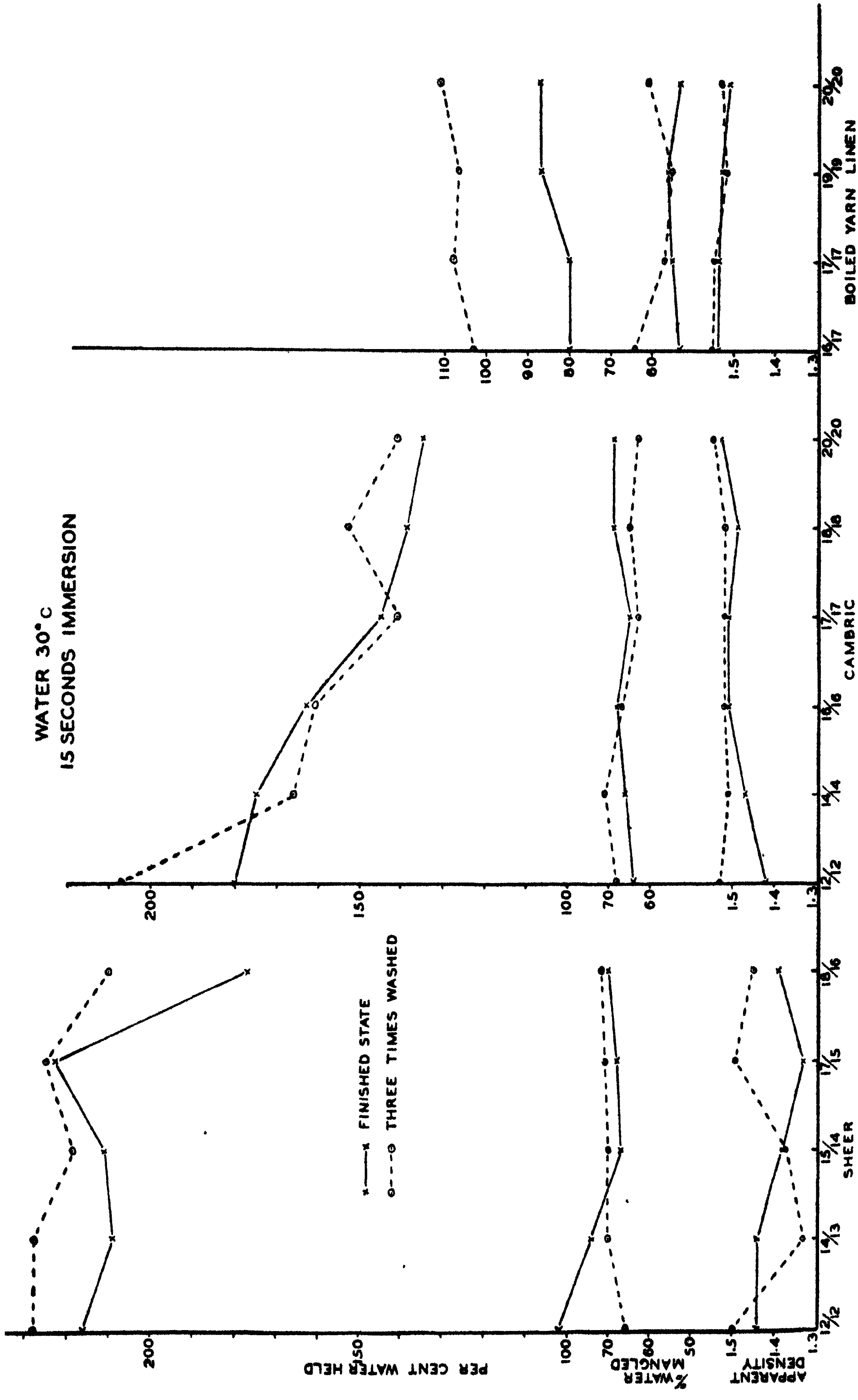

WATER 30°C
15 SECONDS IMMERSION
×——× FINISHED STATE
⊙- - -⊙ THREE TIMES WASHED
PER CENT WATER HELD
% WATER MANGLED
APPARENT DENSITY
200
150
100
70
60
50
1.5
1.4
1.3
110
90
80
12/12
14/13
15/14
17/15
18/16
SHEER
12/12
14/14
16/16
17/17
18/18
20/20
CAMBRIC
16/17
17/17
19/19
20/20
BOILED YARN LINEN

Fig. 7

from warehouse stocks of these standard fabrics, in the fully bleached and finished conditions. In each class, a series of samples is obtained in which the cloth is made up to a fairly constant weight per square yard by weaving warp and weft yarns of increasing fineness with a greater number of warp and weft ends per inch. The yarn settings are not quite in proportion to the changes in the yarn count, so that some variations in weight and compactness of the cloths are shown.

Table V

Particulars of Bleached Fabrics in Finished State

Ref. No.	Description	Yarn Count (nominal) Warp	Yarn Count (nominal) Weft	Ends per inch Warp	Ends per inch Weft	Wt./sq. yard, ounces	Apparent Density Compactness
122 C	Sheer 12°°/12	100	130	71·25	62·2	1·76	0·23
123 C	,, 14/13	110	140	76·25	68·25	1·75	0·31
124 C	,, 15/14	120	150	81·25	71·0	1·88	0·31
125 C	,, 17/15	140	170	93·75	75·25	1·62	0·28
126 C	,, 18/16	150	180	96·75	84·0	1·59	0·27
128 C	Cambric 12°°/12	65	90	64·75	60·0	2·35	0·29
129 C	,, 14/14	75	110	76·25	71·25	2·77	0·32
130 C	,, 16/16	85	130	85·5	81·0	2·44	0·32
131 C	,, 17/17	90	140	92·5	85·75	2·40	0·32
132 C	,, 18/18	100	140	96·75	91·75	2·43	0·34
133 C	,, 20/20	120	160	107·25	100·5	2·33	0·36
134 C	Boiled Yarn Linen 16°°/17	65	90	87·5	85·5	3·33	0·43
135 C	,, ,, ,, 17/17	70	100	91·25	82·75	3·18	0·47
137 C	,, ,, ,, 19/19	80	120	103·5	102·25	2·95	0·46
138 C	,, ,, ,, 20/20	85	130	109·75	99·75	3·04	0·50

The results of the absorbency tests (15 seconds immersion in water at 30° C.) are shown graphically in Fig 7, for cloth in the finished and three times laundered conditions. In the finished state, the completeness of wetting shows some fluctuations with structure, which are not common to each type of cloth; the boiled yarn linens are more completely wetted than the cambric and the latter are more completely wetted than the sheers. The laundered cloths are generally more completely wetted than the finished cloth, and the above difference between the different types is maintained. The chief difference in manufacture would be in the finishing process, which would appear to have a greater effect on the wetting than the size of the yarn.

The per cent. water held after dipping decreases with increasing fineness of cloth in the sheers and also to a greater extent in the cambrics, but in the boiled yarn linen a slight increase is shown. Also it is very clear that the per cent. water held by the sheers is greater than that held by the cambrics which in turn is greater than that held by the boiled yarn linens. These variations in water holding capacity are fairly well explained in agreement with previous conclusions, by reference to the figures for compactness of the cloth. It will be seen from the last column of Table V that the compactness is very high in the boiled yarn linens, and higher with the cambrics than the sheers, and in the cambrics there is a regular and pronounced increase of compactness through the series. In general then the water held is inversely as the apparent density or compactness of the cloth, as was previously indicated in Fig. 5.

The per cent. water held after mangling is fairly constant throughout each series; it decreases in the order sheer, cambric, boiled yarn linen, but the differences are very much smaller than in the case of the water held after dipping. This would appear to show that the water retained in a cloth after a given mangling treatment depends to a slight extent on the compactness of the cloth, but does not depend on the size of the yarn.

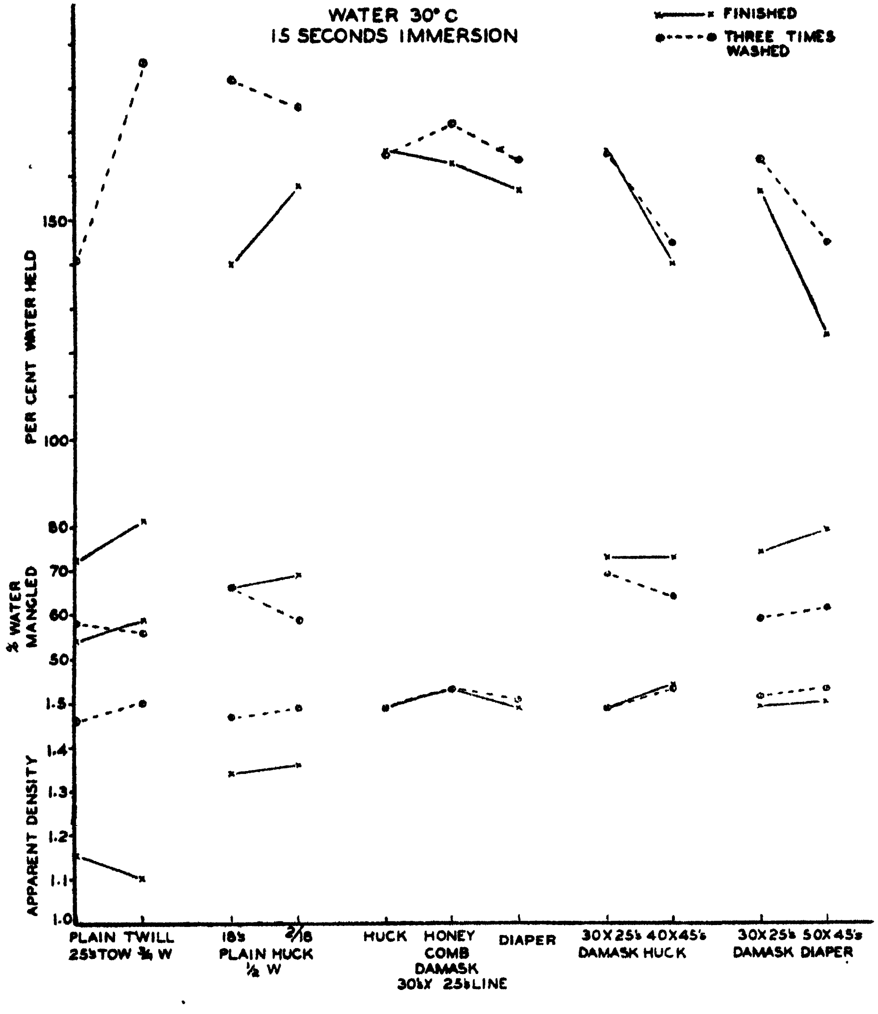


Fig. 8

Effect of Type of Weave

The nature of the effects on absorbency of variation in the type of weave was studied on a selection of linen towels, again drawn from stocks of standard goods. The structural particulars of the samples used are shown in Table VI, and the results of the absorbency measurements (15 seconds immersion in water at 30° C.) are shown graphically in Fig. 8 for the cloth in the finished state and also after being washed three times.

First of all comparing the results from finished cloth (new state) and laundered, it will be seen that the former are very incompletely wetted in the first two cases; wetting is much more complete in the two plain hucks, and in the damask hucks wetting is practically complete. In all cases after laundering the cloths are completely wetted. In the cloths made from the same yarn counts the values for the water held vary in approximately the same manner as the completeness of wetting.

Table VI

Particulars of Linen Towels in Finished State

Ref. No.	Description	Wt./sq. yard, ounces	Ends per inch		Apparent Density Compactness
			Warp	Weft	
144 C	Glass cloth, check plain, 25's tow ¾ W. ...	6·49	43·25	39·5	0·70
145 C	,, ,, bordered twill ,, ,, ...	6·3	43·75	41·0	0·65
146 C	Plain huck, 18's tow, ½ W.	8·69	45·25	49·75	0·52
147 C	,, ,, 2/18's tow, ½ W.	9·07	44·5	59·5	0·53
148 C	Damask huck, 30, 25's line, 4/4 W. ...	7·49	66·5	62·5	0·67
149 C	,, honeycomb ,, ,, ,, .	7·27	66·25	62·25	0·54
150 C	,, diaper ,, ,, ,, ...	6·76	64·5	66·25	0·57
151 C	,, huck, 40, 45's line, 4/4 W. .	6·05	90·0	85·0	0·61
152 C	,, diaper, 50, 45's line ,, ...	5·69	99·0	74·5	0·62

These differences in completeness of wetting of the cloth in the finished state and after laundering, are explicable when the finishing treatments are considered. The glass cloths would receive a mangle finish only, and so the warp dressing materials would still be present and retard wetting until removed by laundering. Similarly the plain hucks would only be lightly, if at all, treated before finishing. The slightly greater wetting of the laundered glass cloths would be due to the more complete bleaching of the yarns in these cases. The damask huck cloths would be brought to a full white bleach before finishing, which explains the complete wetting and the small change on laundering.

It is sufficient here to compare the effect of structure in the cases of the laundered cloths.

The first two samples compare similar cloths with plain and twill weaves. The twill weave shows a slightly higher degree of wetting, a very much higher value for per cent. water held after dipping, but not much difference in the water held after mangling. The greater water holding capacity of the twill weave is due to the lower compactness of this cloth. In the plain hucks, the weave is the same, with a variation in the yarns but the resulting cloths are of equal compactness and show but little difference in absorbency.

The next three samples show damask huck cloths from the same yarns, the centres of the cloths being woven with huck, honeycomb, and diaper weaves. The differences in the absorption behaviours are relatively small, but the honeycomb gave the most complete wetting and also the greatest water holding capacity, and it will be seen from the table that this construction also gave the least compactness in the cloth. The next two sets compare damask huck and damask diaper cloths made from coarser and finer yarns. In both cases the finer cloth shows a slightly greater completeness of wetting and a lower per cent. water held after dipping. The results with the damask diapers are again consistent with the compactness values of the cloths, but not in the case of the damask hucks.

On the whole the results confirm the previous conclusions about the benefit of the last stage of bleaching on the ease of wetting, and the general relation between the compactness of the cloth and the water held. The compactness may vary with the type of weave and some variation is thus found in the water holding power of the different types of cloth.

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24—NATURAL AND ACQUIRED RESISTANCE OF ANIMAL HAIRS TO MICROBIOLOGICAL AGENCIES

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In a previous paper[4] a technique was described involving the use of trypsin as a means of determining the resistance of wool to bacterial action. The modification of fibre resistance by certain chemical processes such as chlorination, chroming, treatment with Eulan N and the variability of natural wools to resist bacterial attack were also noted.

This paper deals more fully with such variations and puts forward suggestions for rendering protection to wool goods hitherto liable in practice to deterioration by bacteria.

A—RESISTANCE OF NATURAL FIBRES AND PROCESSED MATERIALS

Series of raw and partly processed or finished materials have been examined for resistance to trypsin, with the object of ascertaining more clearly the extent of natural variations in the fibres and the effect of manufacturing processes.

The preparation of the materials varied with their nature; raw fibres were cleaned in three baths of ether and three of water, the first water bath containing a little wetting agent; commercial materials in oil were cleansed with 0·2% potash olive oil soft soap and well rinsed in water; scoured fabrics were not given further treatment.

The samples, each weighing 0·1 g. were exposed to the action of 10 cc. of 0·25% buffered trypsin solution, as previously described, and examined at intervals.

RESULTS

(a) Natural Fibres

Table I

Disintegration of Natural Animal Hairs by Trypsin at 35° C.

Annotation (arbitrary scale of values for the amount of cortical cell separation)-

0 = No disintegration.
2 = Slight disintegration.
5 = Noticeable disintegration.
7 = Pronounced disintegration.
10 = Very severe disintegration.

No.	Material	Microscopical Observations 6 hrs.	1 day	7 days	Remarks Further reference to previous (7 days) column
1	Wool; 70's Tasmanian (tips removed)	0	1	3	Actual damage greater than value indicated (3) (probably 5–6).
2	Wool; 70's Tasmanian (tips not removed)	0	2	3	Actual damage greater than value indicated (3) (probably 5–6).
3	Wool; 70's Merino—pigmented	0	0	6	Pigment granules present in cortical cells.
4	Wool; Hungarian	2	4	9	—
5	Wool; Romney	0	8	10	—
6	Wool; Low Canadian Crossbred 48/50's	0	1	6	—
7	Wool; B.A. 46's Crossbred ...	0	2	5	Actual damage slightly more than 5.
8	Wool; Welsh black	0	2	7	(Pigment in the cortical cells. Actual damage slightly greater than 7.)
9	Wool; Kempy	2	6	10	Medulla hollow after tryptic action.
10	Wool; Herdwick (shoulder) ...	0	1	7	Damage slightly more than 7.

Table I—*continued*

		Microscopical Observations			Remarks Further reference to previous (7 days) column
No.	Material	6 hrs.	1 day	7 days	
11	Wool; Low Iceland Fleece (fine wool portions)	0	1	5	Damage equivalent to 7.
12	Wool; Low Iceland Fleece (outer coat)	0	0	5	Damage equivalent to 7.
13	Cashmere; raw white	1	5	10	Fine fibres more susceptible to disintegration than the kempy.
14	Vicuna	1	5	8	—
15	Camel hair; Chinese	—	9	10	—
16	Camel hair; Asiatic	5	9	10	—
17	Alpaca; Arequipa, fawn	1	5	9	Damage slightly more than 9
18	Alpaca; Arequipa, white	0	1	7	—
19	Mohair; Fine Cape Matchings	—	3	10	—
20	Mohair; Turkish	0	2	8	—
21	Mohair	—	9	10	—
22	Goat hair; Chinese grey	0	1	5 6	Beard hairs 5; wool hairs 6.
23	Horse hair; black	0	0	0	Negligible disintegration. Pigment granules noticeable in cortical cells.
24	Human hair; Chinese stump	0	0	0	—
25	Human hair; brunette	0	0	0	—
26	Dog hair; fawn	0	1	6	Actual damage slightly more than 6.
27	Calf hair	0	0	0	—
28	Rabbit	0	1	7	Actual damage slightly more than 7. Some cells show scalariform markings.
29	Rabbit; English Angora	0	1	1	—
30	Rabbit; French Angora	0	1	3	Actual damage somewhat more than 3.
31	Pig hair	0	0	0	—
32	Guinea Pig hair	0	0	5	Some cells show scalariform markings.
33	Musk Rat hair	5	8	10	Some cells show scalariform markings.

The method of recording the degree of fibre disintegration has in some cases, particularly fine wools, a limitation in that although the natural adhesion of the cortical cells to one another may obviously be impaired, these elements do not separate on account of a marked tenacity or interlocking of the epithelial scales. This is indicated in the "Remarks" column, e.g. 70's Tasmanian wool. This difficulty is partly overcome by subjecting the fibres to slight friction.

The number of specimens examined is too small to allow of more than general inferences. On the whole, however, fibres of sheep's wool show good resistance to tryptic and hence microbiological influences. The slight disintegration taking place during the first day is due mostly to pre-existing local weaknesses in the fibres. It appears that the penetration of the digestive fluid through a sound fibre is markedly slow.

Many of the stronger hairs, e.g. horse, human, calf and pig, show pronounced resistance which is overcome only extremely slowly. By subjecting such trypsin-exposed hairs to slight friction in water, it is sometimes possible to isolate in pure form the epithelial scales from the rest of the fibre.

Camel hair proves to be particularly susceptible to attack.

In passing, reference may be made to the scalariform markings present on the periphery of some cells of the rabbit and guinea pig (Figs. 1 and 2) hair, a feature associated no doubt with the latticed appearance shown by the fibres of these and numerous other animals. A further point of interest is the presence of pigment granules within the cortical cells of coloured fibres such as black Welsh wool and horse hair. In aqueous mounting fluid these granules have been observed to show Brownian movement.

The investigation was extended to include certain other substances of animal origin, small portions being placed in the reagent.

Sheep's Horn—Softening of the material and considerable retting occurred within one day's incubation, the horn disintegrating into platelet-like cells. A small clearer space within each cell suggested the positions of a former nucleus.

Cow's Horn—This behaved in a similar manner to sheep's horn and also resolved itself into angular platelets.

Finger Nail—Softening of the material occurred within one day, especially on the outer surface. From the latter could be readily detached constituent plate-like cells, resembling somewhat those of horn. Disintegration of the mass proceeded somewhat slowly unless facilitated by repeated removals of the loosened surface cells.

Whale Bone—This keratinous substance broke down into flattened, elongated, angular platelets in a similar manner to finger nail. The cells also showed nuclear positions and contained pigment granules.

Porcupine Quill—This disintegrated very slowly into flat, pointed cells.

The significance of the cellular nature of the four preceding substances is discussed by Astbury[1] who also gives illustrations of the separated elements.

Thus in addition to facilitating the study of the animal hair, the trypsin solution may be used with advantage in pursuance of certain histological investigations.

By way of interest samples of raw degummed Bombyx silk and of spider silk were exposed to trypsin with no visible change in the appearance of the filaments.

(b) Processed Materials

As this investigation progressed it became evident that the resistance to trypsin exhibited by the raw wool itself, shown above to vary with different samples, played a prominent part in the reactions of the fibre to manufacturing processes. It is felt that this variation shown by different lots of wool is a factor of importance in determining their behaviour during manipulation, storage and use. The results obtained may be stated briefly to the effect that, in general, the wet processes, e.g. soap scouring, chlorination, and to a less extent the mechanical processes, tend to enhance the rate of breakdown in trypsin solution.

B—RESISTANCE OF CHEMICALLY-TREATED MATERIALS

(1) Chrome and Eulan N

The resistance to bacteria imparted by treatment with bichromate and Eulan N previously noted[4], has been further investigated with a view to commercial use.

Using the technique already described, tests have been made with chromed and Eulan-treated wool.

(i) *Chrome dyed-wool*—Fifty-seven variously dyed samples of 60's worsted cloth were exposed to trypsin solution for one day at 35° C. and then microscopically examined. Of 6 samples chrome-mordanted (potassium bi-tartrate) before dyeing, 3 showed very slight and 3 no disintegration. Three samples dyed with metachrome mordant showed slight to fairly pronounced disintegration. Of 27 after-chromed samples, 2 showed very slight breaking down and the others no disintegration. The remaining samples were unchromed and comprised 20 acid dyed fabrics and one dyed with a direct cotton colour; all underwent fairly severe disintegration and their bleeding of dye contrasted markedly with an almost complete absence of bleeding in the case of the chromed wools.

(ii) *Comparison of Protective Values of Chrome and Eulan N*—Worsted cloth was immersed in baths containing potassium bichromate or/and Eulan N, raised slowly to the boil, boiled for 15 minutes, and washed off in running water. The baths were not exhausted of chrome. Portions were subjected to the action of trypsin.

RESULTS

Table II

Comparison of Protective Values of Chrome and Eulan N

(For annotation see Table I)

No.	Treatment	Microscopical Observations		
		1 day	7 days	Prolonged Exposure
1	Control (water only)	8	9	—
2	0·5% chrome ($K_2Cr_2O_7$)	8	9	—
3	1·0% chrome	8	9	—
4	2·0% chrome	7	8	—
5	4·0% chrome	6	7	
6	0·5% chrome plus 0·25% sulphuric acid	7	8	—
7	2·0% chrome plus 1·0% sulphuric acid	2	6	6 weeks : 9
8	4.0% chrome plus 2·0% sulphuric acid	0	2	6 weeks : 6
9	4·0% chrome plus 2·0% acetic acid	2	7	—
10	8·0% chrome plus 4·0% sulphuric acid	0	0	5 weeks : 3
11	2·0% chrome plus 1% sulphuric plus 10% Glauber's salt	2	6	—
12	2% chrome plus 1% sulphuric plus 10% Glaubers salt plus 3% Eulan N	0	2	6 weeks : 5
13	1% sulphuric plus 3% Eulan N	5	—	12 days : 8
14	3% sulphuric plus 10% Eulan N	0	—	12 days : 3
15	1% sulphuric plus 10% Glauber's plus 3% Eulan N	5	6	6 weeks : 9
16	1% sulphuric plus 10% Glauber's	7	10	—
17	4% chrome plus 2% sulphuric plus 3% Eulan N	0	0	5 weeks : 0
18	2% sulphuric plus 3% Eulan N	5	7	—
19	2% sulphuric	8	9	—

Apart from their interest chemically, these results present several points of importance. A strong chrome-sulphuric acid bath, viz. Nos. 8 and 10, produces great resistance to trypsin. Eulan N, while known to impart considerable protection against bacteria, gives much less resistance to trypsin than chrome. Used in conjunction with chrome (cf. Nos. 11, 12, and 13) it adds materially to the protective effect.

(iii) *Action of Chrome and Eulan*—Evidence is to be found in the literature to the effect that when applied in a hot acid bath both chrome and Eulan N combine chemically with wool. The reactivity of the so-called cementing substance towards trypsin is probably influenced by this change. Hot treatment of the material described in Table II, No. 10, with fairly strong ammonium hydroxide solution lowered somewhat the resistance to trypsin but commercial alkaline solutions, e.g. a soap-alkali scouring fluid, did not affect it.

The possibility of the free chrome or Eulan N inhibiting directly the tryptic disintegration, was discounted by the fact that quantities of these substances added to the trypsin solution, failed to check its action upon sound wool.

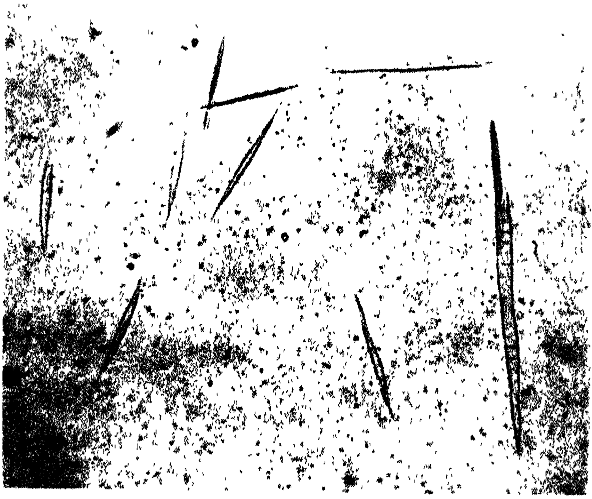

FIG. 1

Cells of Rabbit Hair × 200

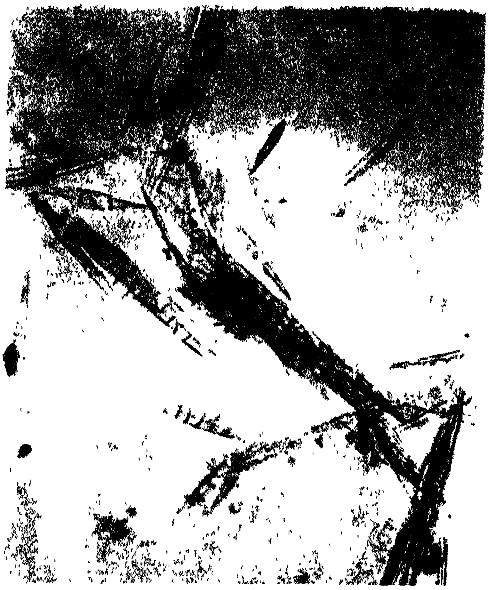

FIG. 2

Cells of Guinea-Pig Hair. × 200.

The protective value of these substances is therefore an attribute of the compound which they form with the wool.

Presumably they react with and tie together the acid and basic linkages between the peptide chains of the fibre as suggested by Speakman,[7] and in addition, effect a blocking of cell interstices by the precipitation of chrome compounds.

It would appear from Table II, however, that the action of chrome and Eulan N are not identical.

(iv) *Reduced and Oxidised Chrome*—Worsted cloth was boiled for one hour in baths of the following composition—

A 3% bichromate and 2·5% cream of tartar
B 4% bichromate and 3% cream of tartar
C 3% bichromate and 5% lactic acid
D 2% bichromate and 2% formic acid
E 3% bichromate and 1% sulphuric acid
F water alone

Pattern E was latter immersed in dilute sodium bisulphite until the colour became green and then rinsed. Portions of A, B and C were dyed with 3% acetic acid, and 5% Eriochrome Red B (Geigy), and of D, E and F with 3% acetic acid and 5% Eriochrome Orange R (Geigy).

All were subjected to the trypsin test and while after 24 hours exposure, pattern F showed serious disintegration, patterns A, B and D exhibited only slight evidence, and patterns B and E no evidence of attack.

Hence reduced and oxidised chrome also give pronounced protection.

(v) *Protection of Damaged Wool*—Fabrics previously damaged by chlorination were treated with chrome and Eulan N, and the effect of trypsin noted.

Table III

Protection of Damaged Wool by Chrome and Eulan N

No.		Material and Treatment	Microscopical Observations	
			1 day	7 days
1	Fabric No. 1	(badly damaged), control	10	-
2	,,	plus 4% chrome plus 2% sulphuric acid	10	-
3	,,	plus 4% chrome plus 2% sulphuric plus 3% Eulan N	10	-
4	Fabric No. 2	(fairly badly damaged), control	10	
5	,,	plus 2% chrome plus 1% sulphuric	9	10
6	,,	plus 2% chrome plus 1% sulphuric plus 10% Glauber's plus 3% Eulan N	8	10
7	,,	plus 4% chrome plus 2% sulphuric	5	9
8	,,	plus 4% chrome plus 2% sulphuric plus 3% Eulan N	4	7
9	,,	plus 8% chrome plus 4% sulphuric	10	

Thus, provided initial fibre injury has not proceeded too far, it is possible by means of chrome and Eulan N, to give some measure of protection to the wool. Excess of chrome has no beneficial effect.

Additional experiments showed that the beneficial effects derived from chroming and treatment with Eulan N at the boil, do not result if treatment is carried out at 60° C. A further point is that the resistance to proteolysis shown by commercially chromed materials is not impaired by a normal milling process.

(vi) *Protective Action of Chrome and Eulan N against Micro-organisms*—Further tests with micro-organisms were carried out to supplement the previously described experiments[4] with *Bacillus mesentericus ruber*.

Pieces of fabric, one gram in weight, were steam-sterilised in plugged flasks containing 50 cc. of a 3% solution of standard nutrient broth. The liquids were inoculated with cultures of strong wool-decomposing organisms.

Table IV

Protective Action of Chrome and Eulan N against Wool-disintegrating Micro-organisms. (13 days' incubation at 23° C.)

(Annotation as in Table I)

Material	Microscopical Observations			
	Bacillus mesentericus ruber	*Actinomyces flavus*	*Trichoderma* sp.	*Fusarium* sp.
60's worsted cloth in normal condition ...	10	10	6	10
Knitted Botany fabric rendered unshrinkable by chlorination	10	10	10	10
Woven baby bag fabric dyed and rendered unshrinkable	10	10	10	10
60's worsted cloth treated with 4% bichrome and 2% sulphuric acid	0	6	0	8 (In region of concentrated growth, elsewhere 0–1.)
60's worsted cloth treated with 3% Eulan N and 2% sulphuric acid	6	10	5	8

While a normal commercial cloth (No. 1) and damaged materials (Nos. 2 and 3) succumb to the action of all the organisms, chromed cloth (No. 4) and to a less extent Eulan N-treated cloth (No. 5) resist *Bacillus mesentericus ruber*. The last two treatments do not afford as much protection against Actinomyces and species of Mould Fungi, which exercise very strong wool-disintegrating properties.

An equally severe test of the efficacy of the various treatments involved the exposure of fabrics foı three weeks in a moist loamy soil rich in humus and vegetable matter. Typical results, including those obtained with cutch-treated wool, which is referred to later, are as follows—

Table V

Exposure of Treated Fabrics in the Soil for 21 Days at 23° C. and to Trypsin for 24 hours at 35° C.

No.	Material	Treatment	Soil exposed	Trypsin exposed
1	Worsted cloth ...	8% Eriochrome Black T, 6% acetic acid, 1½% potassium bichromate.	Good condition.	0
2	Worsted cloth ...	As (1) plus 3% Eulan N.	Particularly good condition, almost unaffected.	0
3	Worsted cloth ...	3% potassium bichromate, 5% lactic acid.	Good condition.	0
4	Worsted cloth ...	3% potassium bichromate, 1% sulphuric, then reduced with sodium bisulphite.	Good condition.	0
5	Worsted cloth ...	10% cutch, 1% copper sulphate, followed by 2% potassium bichromate.	Good condition.	0
6	Worsted cloth ...	10% cutch, 2% copper sulphate.	Good condition.	0
7	Felt	3% Eulan N, 1% sulphuric acid, 2% acetic acid.	Somewhat weak condition.	5
8	Worsted cloth ...	4% potassium bichromate. 3% cream of tartar.	Weakish condition.	2
9	Worsted cloth ...	2% potassium bichromate, 2% formic acid.	Quite weak.	5
10	Worsted cloth ...	Control.	Very bad condition (rotten).	8
11	Felt.	Control.	Very weak condition.	7

Comparison of the results in the soil test with those obtained for the same materials in the trypsin tests, gives further evidence of the value of the trypsin test as a means of assessing the resistance of chemically treated wool to microbiological attack.

(2) Other Chemical Treatments

Many other treatments, including the usual mordanting processes, which might influence the resistant properties of the fibre to proteolytic enzymes were considered. Some, e.g. treatment with formaldehyde[8], aluminium compounds, benzoquinone, were found to give some, but by no means complete protection against bacteria. With the exception of cutch-treated wool, none of the materials resisted the trypsin solution to the same degree as chromed wool.

Cutch, which is used for preserving certain vegetable fabrics[2,6], gave interesting results as follows—

Table VI

Resistance of Cutch-treated Wool to Trypsin and *Bacillus mesentericus ruber* at 35° C.

No.	Treatment	Microscopical Observations Trypsin 1 day	Microscopical Observations Trypsin 7 days	*Bacillus mesentericus ruber* 14 days
1	Worsted cloth boiled with 10% Burmah Cutch plus 1% copper sulphate Later boiled with 2% potassium bichromate	0	0	0
2	10% Cutch. Subsequently boiled 30 minutes with water	2	10	9
3	As (2), subsequently boiled with 2% copper sulphate	0	2	0
4	As (2), subsequently boiled with 2% ferrous sulphate	0	6	2
5	As (2), subsequently boiled with 2% potassium bichromate	0	1	0
6	Boiled with 2% copper sulphate	6	10	0
7	Boiled with 2% ferrous sulphate	6	10	10
8	Boiled with 2% potassium bichromate	6	10	8

Cutch alone gives inadequate protection but when combined with ferrous or copper sulphate or potassium bichromate, its application is very beneficial. It was noticed that bacterial growth was checked in the case of copper sulphate-treated wool, due presumably to the bactericidal properties of the copper.

Since, however, both chromed wool and wool dyed with cutch have limited ranges of utility, as, for example, in the case of dyed goods, the search for other treatments is being continued. In passing it may be mentioned that the trypsin test has been found of much value in indicating fibre damage caused by agents other than micro-biological, as for example, damage by mild acid and alkali. Its application is limited, however, by its inability to disintegrate chromed wool.

C—APPLICATION OF RESULTS

There are in practice many cases where wool may be left wet for periods sufficiently long for bacterial action to cause deterioration of the fibre. Of such instances, four will be briefly mentioned. As previously pointed out[4], their resistance to retting ferments may be a more preferable objective than the impregnation of the fibre with a very sparingly-soluble bactericidal substance, but chemical combination might interfere with the practical action of wool to a greater extent than would simple impregnation.

(*a*) *Bathing Costumes*—These are known to deteriorate prematurely in warm climates, due to having been repeatedly left wet[3]. Chrome dyed wool would resist this action and where the desired colours are beyond the colour range permitted by chroming, Eulan N may be used.

(*b*) *Baby Bag Materials*—Many cases have come to hand of garments of the above fabrics undergoing rapid deterioration, and investigation has located the cause as being bacterial. Organisms of the coccus type are present in urine which, utilising the latter as a source of nutriment, secrete fibre-disintegrating enzymes. The protection of such fabrics may be a more difficult matter owing to the sensitiveness of children's skin, and in the absence of specific tests, unqualified recommendations cannot be made. In the writer's view, there appears no reason to suspect that the use of Eulan N, which behaves as a typical acid dyestuff, should lead to trouble, while fabrics treated with reduced chromates entirely free from unreduced chromate, are worthy of consideration.

(*c*) *Paper Makers' Felts*—The deterioration of these through being left wet has long been known[5], and a search for a suitable means of their preservation is being undertaken in co-operation with a well-known firm of paper manufacturers. Numbers of felts treated with chrome, Eulan N and cutch have given satisfactory results when examined by the laboratory tests, but have not proved entirely satisfactory under practical conditions owing to modifications in their water-absorbing power.

A protective treatment must here be carried out in the scoured wool stage.

(*d*) *Roller Lapping*—This material is a twisted sliver of Lincoln Hog wool, used for covering the upper squeeze roller in wool scouring machines. Its deterioration may possibly be due to one or several factors, as for example, alkali action, mechanical pressure or bacterial influence. Participation of the last agent is suggested by the fact that the lapping often bursts from the interior outwards, emitting at the same time an offensive odour. The fibres contain large numbers of bacteria and show the type of damage associated with bacterial action. In the light of the above results this problem is also receiving attention.

D—SUMMARY AND CONCLUSIONS

1—The value of a previously reported standard test involving the use of trypsin solution as a means of determining the resistance of wool and other animal hairs to bacterial attack, has been further explored with special reference to raw and processed materials and the action of certain chemical treatments.

2—Unprocessed animal hairs vary considerably in their resistance to trypsin, a feature which perhaps plays an important part in determining the behaviour of such materials during certain manipulative processes and use.

3—Results of previous work with chrome and Eulan N have been confirmed. Chrome, applied as in normal dyeing procedures, gives pronounced protection against bacteria and to a less extent, strong wool-decomposing mould fungi. Eulan N gives less protection than chrome, but when used with it, the effect of chrome is much enhanced.

Their action is due to a chemical modification of the fibre, relative to proteolytic enzyme action, rather than to any bactericidal effect.

4—Combined treatment with cutch and chrome or cutch and copper sulphate imparts good protection against bacteria.

5—Recommendations are made for the practical application of the results obtained.

6—The use of trypsin for purposes other than the assessment of susceptibility to bacterial attack, as for example, in histological work and the testing of textile materials is suggested.

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